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Designing for Shareable Interfaces In The Wild

Richard Stuart Morris

SUBMITTED TO THE DEPARTMENT OF COMPUTER SCIENCE OF
THE OPEN UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

December 2013

Papers Related to this Research

Part of the work presented in this thesis has also appeared in various forms below. The work is part of the ShareIT project funded by the EPSRC, grant number EP/F017324/1. The papers below and the user-studies reported within were the product a collaborative effort between myself and ShareIT team member Paul Marshall, and my supervisor Prof. Yvonne Rogers. Additional contributions were made by Stefan Kreitmayer and Matt Davies for the creation of one of the prototypes.

My contributions to this collaborative work included the creation of the core concepts, design and development of the prototypes, planning, design, and running of the user studies, and the analysis. The conceptual contributions, analysis, and discussion carried out in this thesis is entirely my own work, and extends the below papers considerably.

Morris, R., Marshall, P. and Rogers, Y. (2008) Analysing Fluid Interaction across Multiple Displays. AVI '08, May 31 2008. Retrieved from http://www.hitlab.utas.edu.au/w/images/7/7e/08_ppd.pdf

Morris, R. (2009) Designing Technology for Reflection on Experience: Supporting Collaboration and Reflection with Digital Tabletops. CHI '09 Workshop. Retrieved from <http://www.comp.lancs.ac.uk/~corina/CHI09Workshop/Papers/Morris.pdf>

Marshall, P., Morris, R., Rogers, Y., Kreitmayer, S. and Davies, M. (2011) Rethinking 'Multi-user': an In-the-Wild Study of how Groups Approach a Walk-Up-and-Use Tabletop, CHI '11, ACM, 3033-3042.

Abstract

Despite excitement about the potential of interactive tabletops to support collaborative work, there have been few empirical demonstrations of their effectiveness (Marshall et al., 2011). In particular, while lab-based studies have explored the effects of individual design features, there has been a dearth of studies evaluating the success of systems in the wild. For this technology to be of value, designers and systems builders require a better understanding of how to develop and evaluate tabletop applications to be deployed in real world settings.

This dissertation reports on two systems designed through a process that incorporated ethnography-style observations, iterative design and in the wild evaluation. The first study focused on collaborative learning in a medical setting. To address the fact that visitors to a hospital emergency ward were leaving with an incomplete understanding of their diagnosis and treatment, a system was prototyped in a working Emergency Room (ER) with doctors and patients. The system was found to be helpful but adoption issues hampered its impact. The second study focused on a planning application for visitors to a tourist information centre. Issues and opportunities for a successful, contextually-fitted system were addressed and it was found to be effective in supporting group planning activities by novice users, in particular, facilitating users' first experiences, providing effective signage and offering assistance to guide the user through the application.

This dissertation contributes to understanding of multi-user systems through literature review of tabletop systems, collaborative tasks, design frameworks

and evaluation of prototypes. Some support was found for the claim that tabletops are a useful technology for collaboration, and several issues were discussed. Contributions to understanding in this field are delivered through design guidelines, heuristics, frameworks, and recommendations, in addition to the two case studies to help guide future tabletop system creators.

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1 Introduction

1.1 Background to this Course of Research

This thesis explores the problem space of designing applications for digital interactive tabletops, a genre of interactive system characterised by having a large horizontal touchscreen that can be used simultaneously by two or more people. An analysis of prior research reported in Chapter 2 shows that, despite the physical technology becoming more mature, the issues and concepts of designing applications to successfully exploit the potential of this technology are still in their infancy (Remy *et al.*, 2010). In particular, because of their shareable nature, it has been suggested that tabletops are useful for collaborative activities (Benko *et al.*, 2009). However, very few studies have explored this assertion outside of a laboratory setting (Hornecker, 2008), and it is unclear whether findings from the laboratory transfer easily to in the wild settings (Marshall *et al.*, 2011).



Figure 1.1: People exploring digital information in a collaborative way using a Microsoft PixelSense SUR40.

The most common form of human-computer interaction is a single user using a PC, such as a laptop. Given the differences in ergonomics, user configurations and interaction methods between PCs and tabletop computers, the need arises to ask what are suitable applications for these tabletops and how can we best design for them? The technology for tabletop computers continues to mature, but the applications designed for them do not seem to have made an impact on our day-to-day lives. To date, tabletops have been used as a technology to support various collocated activities, including games and photo sorting (Rogers *et al.*, 2006), but can tabletops help us work better in planning, problem solving and learning? As one researcher notes:

"Developing good applications is not a trivial enterprise, even if the underlying technology is becoming so." (Schöning et al., 2009)

And while the technology is fascinating, it is not nearly as important as the possibilities it introduces and the potential world it can create. As often happens in innovation cycles with technology, the vision for how people can collaborate and create together is formed only after the 'newness' of the technology has worn off. It is the privilege of this researcher to apply the technology in ways that hopefully lead to insights about our environments and ourselves. Since technology serves humanity it should be our mission to enhance our human systems and augment human experience. The greatest technologies of our time allow us to work in powerful new ways and the most potent promise of shareable technologies is to enable working in a shared intellectual space. This is as opposed to the Personal Computing era; the large multi-user systems of today let us combine our individual creative forces and multiply them through powerful technology and distributed networks.

Compared to PCs, tabletop computers have the additional affordance of allowing multiple users to interact with the same application simultaneously and to use multi-touch gestures. The users can also arrange themselves around a tabletop computer in various ways that allow for easy collaboration and the full awareness of body language, hand and arm gestures, relative position and to make use of good eye contact. What new kinds of software systems can take advantage of all these good collaborative benefits and extend them with digital media and computation?

There are many urgent and meaningful problems for which shareable technology could be a useful solution. However, creating successful tabletop systems is difficult (Baker *et al.*, 2002) and, although becoming more popular, there have not been many examples of real-world tabletop systems being deployed and evaluated outside of the lab. Designers and developers can benefit from a better understanding of the challenges and opportunities of this new technological and social opportunity. Frameworks and design guidelines, as well as experience reports and case studies from real-world deployments of tabletop interfaces in public settings can be of value to the next generation of technologists.

1.2 Research Objectives

This course of research has the following principle objectives:

1. To gain an understanding of the problem space of designing for collaborative activities with interactive tabletops. Primarily, this means identifying the most important factors that affect tabletop application design. This is approached through a thorough review of related

literature and exploration through first-hand observation, design and evaluation of tabletop systems for real-world contexts.

2. To propose a framework for the development of tabletop systems for in-the-wild contexts which addresses areas of weakness in existing research and to propose solutions. This is mainly achieved through approaches and heuristics found to be effective when applied to the scenarios chosen for application development in this course of research. This mainly addresses a) the selection of appropriate activities for support with tabletops and b) the effective support of these tasks with an approach to developing and improving the applications in the wild.
3. To discover the extent to which tabletops can support co-located collaboration and to explore the potential of using this new technology in the wild.
4. To build and evaluate two complementary systems from grounded observation, making design decisions, and providing richly detailed case studies, as a platform for exploring the above frameworks, and to serve as experience reports for future tabletop systems designers.
5. To contribute to the understanding of the important discriminating factors and key issues relating to tabletop systems and propose a set of design guidelines for tabletop applications based on the findings of this course of research.

The contributions described below are the outcome of this course of research, guided by the above objectives. Through the course of two studies and comprehensive literature review, the following contributions were developed

throughout this course of research, in addressing the concrete problems of building prototypes for the two studies, and in analysis of the results and reflection on the insights garnered in summary.

1.3 Contributions

Tabletop technologies continue to mature and the widespread acceptance of multi-touch gestures reduces the gulf of execution for novice users. Tabletop and other multi-user systems will continue to migrate from research labs to the commercial arena and this thesis will provide a critical stepping-stone between those two worlds. As will be shown, the work in the lab cannot always be successfully transferred into “the wild.” Therefore, it is crucial to evaluate these systems in messy, unpredictable real world settings, and to identify which key features of tabletops will make a robust improvement in the lives of both novice and expert users. Not only does the placement of technology in public settings prove challenging for many reasons, but identifying the common goal of people in a given situated space can be elusive.

A key contribution of this thesis is that it provides in-depth coverage of two tabletop studies, design guidelines and heuristics for researchers and system designers, helping them to understand the interplay between the physical characteristics, interface issues, social behaviour, context and design methods which contribute to successful tabletop systems. Key contributions include:

Methodological Contributions

Lean Observe-Build Methodology

This approach includes cross-functional pairing and other design mentalities not before applied to tabletop development, bringing together discovery research and design work, followed by rapid iterative development *in situ*.

Conceptual Contributions

- A definition of fluidity and description of fluidity heuristics
- Application of Cynefin framework and temporal thinking styles
- An application of an Activity-Centred Design approach as applied to multi-user technologies and in-the-wild evaluation
- Evaluation of context using Technology Complex
- IDEAS Framework – a scaffold for evaluating context for tabletop systems

Experience Contributions

- Two in-depth in-the-wild studies, from initial ethnographies, through design, deployment, and evaluation.
- Consideration of related work and extension of pre-existing findings and frameworks to include the findings of this course of research.
- Empirical findings – these include conceptualizations of how people interact and work together when collaborating at tabletop computers in public settings

In solving the problems that arose from creating the prototypes built for this course of research, a number of new approaches were formed and evaluated.

These approaches were informed by existing and novel frameworks, based on review of the literature and early exploration with the hardware and applications. The frameworks are presented based on these findings, as described below, that can be generally applied to similar problems, and which can serve as sensitising concepts for designers and researchers of future tabletop systems. Such frameworks are:

1.3.1 Fluidity Framework

It is a challenge creating a system that provides support for the goals of multiple users. The fluidity framework is a heuristic and a 'design lens' for considering how well an interface solution supports the higher-level goals of its users. By considering the ultimate objective of the users versus the lower-order interactions and operations they must perform to achieve their goal, the designer or developer of a multi-touch system can maintain a better perspective of the usefulness of the system and the success of their interface solution.

The fluidity framework is developed from a review of the literature and an early exploration of the affordances on tabletop systems at the outset of this course of study. It was used in the design, development, and in-place evaluation of the two studies described in this thesis and discussed in relation to design principles for tabletop systems in chapter 9.

1.3.2 IDEAS Framework

The IDEAS framework is an acronym standing for: Interface, Device, Environment, Application, and Social. It is a five-factor framework to consider design options and compare design solutions in a systematic and synergistic

fashion. By breaking down the complex factors which contribute to a real-world system, the designer or developer can gain clarity and insight into how their application will perform and where it will sit in relation to existing solutions. Breaking down the factors of systems allows for more thorough exploration of the important issues with greater depth and clarity. The interaction between the separate factors is also considered.

The IDEAS framework evolves from review of the related literature and is honed in early work with tabletop systems in the course of this research. It is applied to the development of the two studies described in chapters 5-8, and discussed in chapter 9.

1.3.3 User Activity Design

As well as overall guidelines for tabletop design, this thesis details a subtle shift in the user-centred design process, with a focus shared between activities and goals. Traditional user-centred design approaches are not equipped to deal with these problems and are likely to fail as a design methodology since, when multiple users are engaging with a system, how do you say who the 'user' is?

Instead of users *per se*, it is preferable to focus on activities, which are composed of tasks, and support those in a lightweight way, taking into account the fact that the users will likely re-appropriate the system and use it in unintended ways, as fits their need. Observing users engaging with system in a live, in-the-wild setting is crucial in understanding how the system affects the users, how they choose to use it and how best to support them in their goals.

Designing for users' goals may not be sufficient when designing for this class of technology. Users' goals may be ill-defined, and the goals may change in concert

with using the system, on discussion with other people, or for no apparent reason. Therefore, it is best to design for a single, clear activity that allows for robust and flexible interaction.

1.3.4 Importance of Context

The context of a technological system is the wider surroundings and social setting into which this system is placed. When designing interactive software, context plays a less or more important role depending on the particular demands of the system. The designer of a word processor for a desktop PC, for example, does not need to be particularly sensitive to the context of its use, as the conventions and constraints of the interaction are well defined and understood. Also, the factors beyond the interface and technology itself do not have a great bearing on the success of the user and the application, typing documents being, usually, a linear single-user task.

This is a contributing factor to its success of such applications – they can be used anywhere, regardless of the specifics of the situation, helped by the rigidity of the interactions. However, for a multi-user collaborative tool the context is much more important, as the edges of the social environment blur with the collaborative interactions, and can have a profound effect on the success or failure of the goals of the designer, and the users.

Single user PC dialogue-based interaction <-> Multi-user, Casual Touchscreen
Insensitive <-----> Highly Sensitive

Figure 1.2: Technology systems and relative importance of context.

As Dey and Abowd (2000) say:

“When humans talk with humans, they are able to use implicit situational information, or context, to increase conversational bandwidth. Unfortunately, this ability to convey ideas does not transfer well to humans interacting with computers... An understanding of context will enable application designers to choose what context to use in their applications. An understanding of how context can be used will help application designers determine what context-aware behaviors to support in their applications.”
pp.1

Abowd *et al.* (1999) discuss the importance of context in relation to ubiquitous computing (ubicomp) scenarios. They suggest that, in order to provide the best experience for users, the designers of a technology should consider as many potential factors that can affect a system and its use, and then make decisions about how these should alter the way in which the system works.

Dourish (2004) suggests that this approach is fundamentally problematic, arguing that the resulting experience of the user is a phenomenological thing, and cannot be approached in a positivist manner. He goes on to say that it is difficult, or impossible, to predict how a resulting system will work out, given that it has an impact on its surroundings, and people's perceptions cannot be predicted. However, he does not make concrete suggestions on how to proceed as a system designer other than to start with lightweight solutions and build out in a reflective and responsive manner.

Multi-user systems are challenging to design for, since the nature of co-located collaboration is very subtle, and the collaborative work is of a highly dense and

synchronous character. It is difficult to fully predict the nature of collaboration that any set of users will employ, or the nature of interruption, both voluntary and involuntary, that will occur. This is especially true for contexts involving members of the public. As Rogers (2011) states:

“Finally, for the wild approach to be valuable to researchers and designers alike, we need to develop wild theories. This will involve abstracting insights from the emerging body of in-the-wild studies, together with evolving some of the newly imported theories and creating nascent ones.” p.62

The particular context of multi-user tabletop systems for collaborative, in the wild use poses several challenges as outlined above. As well making a choices of which activities are appropriate in ambition and scope, there is a need for an effective approach to understanding the goals of the group, the relation of the group’s activities to the situated space, and a way to design and build iteratively, reacting to new insights and the ways in which introducing a technological intervention alters the balance of the socio-contextual systems. The Lean Observe-Build approach was developed in the course of building and evaluating the two prototypes in this course of research.

The importance of context is discussed throughout the thesis. Context is examined in the literature review of in-the-wild tabletop studies. The social and physical contexts of the two studies are observed and interpreted in detail, and the impacts these had on the resulting solutions are described in chapters 5, 6, and 7. The importance of context is evaluated and its relevance to the topic of this thesis is visited again in chapter 9.

1.3.5 Lean Observe-Build Design

Due to the highly complex nature of designing for multiple users, an approach to developing the systems built in the course of research was employed which married principles drawn from lean manufacturing, extreme programming and ethnography. Ideas for the prototypes were based on solid, ethnographically informed, understanding of the context. From there, ideas were quickly developed, from sketch-based concepts, paper-prototypes and user testing to deploying a working prototype as quickly as possible to the intended location.

The fast iteration of the design *in situ* allowed a virtuous cycle of gaining insights through observation of the technology's use, prototyping ideas quickly and observing their effect. With each iteration of the system, new possibilities and ideas were unlocked and progress to a creative and successful solution could be made. The progress of each iteration of the solution can be validated with a 'quick and dirty' round of testing with representative users.

This approach is discussed in detail in chapter 4. It was the main approach applied in the course of the two studies described in this thesis and is evaluated in those chapters and again, overall, in chapter 9.

1.3.6 In-the-wild Design and Evaluation

The core of this thesis is the development of two novel tabletop application prototypes designed in an activity-centred fashion and evaluated in the wild. Informed by academic research of tabletop interfaces and multi-user systems, and using novel techniques for solving the problems of creating successful multi-users systems in real-world settings, these prototypes were deployed and evaluated over two years.

The unique methodological approaches above were employed to positive effect in these two case studies, and the development of the tabletop systems is described along their various stages, with ethnographically-informed discovery, rapid development and testing, and *in situ* iteration and evaluation.

The importance of moving HCI research out of the lab and in to the public sphere is discussed throughout this thesis, and the entirety of chapter 3 is dedicated to reviewing existing literature on this topic. The development and evaluation of frameworks and design principles for the building and assessment of successful in-the-wild multi-user systems continues through both studies (described in chapters 5-8) and is discussed in chapter 9.

1.4 Thesis Structure

This thesis is structured as follows: Chapter 2 provides the background to tabletop research, a literature review, analysis of the problem space, identifying gaps in research, and outlining research questions. Leading on from the lack of in-the-wild studies found in Chapter 2, Chapter 3 explores this aspect in more detail and discusses some methodological points. Chapter 4 details the nascent design frameworks and methodological contributions of the thesis in preparation for the case studies in the following chapters. Chapter 5 details the research, design, deployment and evaluation of HealthTable, an application developed for collaborative learning in a hospital emergency room setting. Following this, two case studies are reported, beginning in Chapter 6 with a description of the series of ethnography-style observations that informed the design of CamPlan, a group planning tabletop application for tourism. The design process for this application is described in Chapter 7 and the evaluation

is contained in Chapter 8. Chapter 9 consists of the thesis discussion, and Chapter 10 contains the conclusions and future work.

2 Literature Review – Tabletop Technologies

This chapter includes a summary of tabletop computer technologies, an overview of the academic literature on shareable interfaces with a focus on tabletops and an overview of the problem space of designing and using tabletop computers. When this research project began in 2006 there was a dearth of *in situ* research into tabletops. Many studies had been conducted in the lab, investigating issues such as interface demands, and a few studies had looked into the benefits of collaboration through using tabletops. This literature review chapter will provide a detailed overview of studies relevant to tabletop system design. The following chapter will discuss the importance of, and issues surrounding, in-the-wild studies.

2.1 Background to Tabletop Technologies

Research on tabletop computing has a history of at least 20 years. In 1991, Wellner developed DigitalDesk, which allowed mixing physical paper with augmented data from an overhead projector. Multi-touch interfaces have an even longer history in industrial research. Bill Buxton maintains a list of multi-touch interfaces¹ identifying the first as being created in 1982.

However, research into tabletop computers surged with the release of commercial hardware platforms such as Mitsubishi DiamondTouch (which first appeared publicly in 2004) and Microsoft Surface (first available in 2008). This

¹ <http://www.billbuxton.com/multitouchOverview.html>

timing corresponds with what Buxton calls the 'long nose of innovation' (Buxton, 2007), which refers to the manner in which technologies which are being developed in research labs tend to have a 20-or-so year period from the first publications to them being mature enough to develop commercially. Also, Han (2005) demonstrated how multi-touch surfaces could be created cheaply and easily using a Frustrated Total Internal Reflection (FTIR) method in a talk presented at TED in 2006. A key advantage of Han's method was that it could lead to designs of various shapes and sizes.

2.1.1 Key Characteristics of Tabletops

Tabletop computers have certain distinct properties that differentiate them from other forms of technology such as: having a large horizontal surface allowing for multiple people to interact simultaneously; having a large touchscreen which allows for direct multi-touch interaction with an application. Other features such as object recognition, or tangible interaction are also a feature of some tabletop systems (e.g. reacTIVision: Kaltenbrunner and Bencina, 2007). This aspect is not used in this course of research, primarily due to the public nature of the prototypes developed meaning tangible objects could go missing.

One of the key characteristics of tabletops is that they are large enough for two or more people to interact with simultaneously. The notion of multi-user systems was developed into Single Display Groupware (Stewart *et al.*, 1999), where applications were developed for co-present users to collaborate using a computer with multiple input devices but a single display.

Groupware of today can make use of multi-touch tabletop displays. A wide variety of tabletop applications have been developed for supporting group activity, from sharing media (Shen *et al.*, 2003), to exploration of scientific data (Shaer *et al.*, 2010), musical performance (Jordà, 2006) and facilitating medical conversations between doctors and deaf patients (Piper & Hollan, 2008).

Benko *et al.*, 2009, conducted a study of long-term tabletop use in personal and professional settings. As the findings displayed in Figure 2.1 show, the unique features of tabletop systems that differentiate them from typical desktop PCs—multi-user support, large display size, multi-touch capability and direct touch—were most favoured as features that support collaborative use among long-term tabletop users. The physics-based manipulations, animations, and novelty factor appealed to novice users. This is important to note for public walk-up-and-use settings.

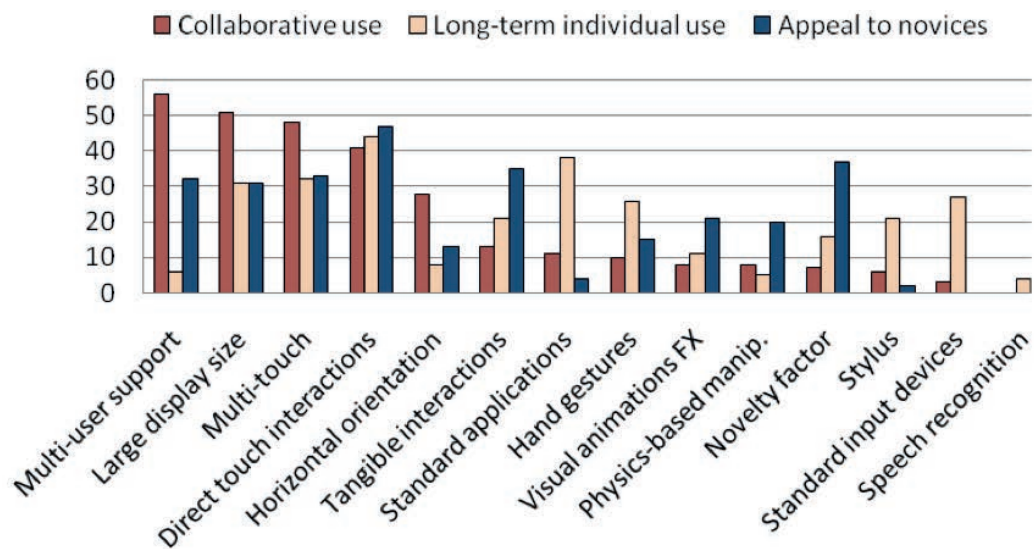


Figure 2.1: Side-by-side comparison of votes for top-five rankings for each of the three usage scenarios in Benko *et al.*, 2009

Collaborative use	Votes	Long-term individual use	Votes	Appeal to novices	Votes
Multi-user support	57	Direct touch	44	Direct touch	48
Large display	53	Standard applications	39	Novelty factor	38
Multi-touch	49	Multi-touch	33	Tangible interactions	36
Direct touch	42	Large display	31	Multi-touch	34
Horizontal orientation	28	Standard input devices	28	Multi-user support	32

Figure 2.2: Aggregated top-five rankings for each of the three usage scenarios from Benko *et al.*, 2009

2.2 Important Factors relating to Tabletop Design

2.2.1 Lab Studies

There have been numerous lab-based studies examining various factors relating to tabletop design. As a new class of device, many of the studies were focused on understanding the nature of specific aspects of interaction. These include orientation (e.g. Kruger *et al.*, 2003; Rogers & Lindley, 2004; Wigdor & Balakrishnan, 2005), table size (e.g. Ryall *et al.*, 2004; Toney & Thomas, 2006), use of space and territoriality (e.g. Scott *et al.*, 2004; Tuddenham & Robinson, 2009), and expressiveness of touch gestures (e.g. Wobbrock *et al.*, 2009; Morris *et al.*, 2010).

2.2.2 Group Work

Where an activity involves more than one person, the activity can usually be described as involving coordination, cooperation or collaboration. Some form of coordination is usually required for any group work, and coordination is necessary for either cooperation or collaboration. Coordination, cooperation and collaboration, in order, describe increasing amounts of inter-dependence and alignment of the goals of the people involved.

Coordination is defined as “the act of managing interdependencies between activities,” (Malone & Crowstone, 1990) and can include processes such as negotiating use of shared resources. For example, if an office has only one stapler it has to be shared between people who are performing unrelated tasks. This coordination may be governed by agreed-upon rule that the stapler is kept in the centre of the room, and returned to the same place after anybody uses it, or one person may keep the stapler, e.g. the receptionist, and this person manages its utilisation.

The coordinating mechanisms allow interdependent work to be coordinated - the work of choosing the objects, mediating mechanisms and common understanding of the functional system can be upfront or continuous. This is the way in which coordination occurs and this allows cooperation (work on unrelated activities which requires sharing of resources) and collaboration (closely-knit work with a single end goal or closely related goals). Although coordination is a standard way of organising work between people, the time and effort necessary to construct and maintain functional systems can sometimes disrupt the work itself (Bly, 1988; Rogers, 1992) and other methods of production may be employed, i.e. an ad-hoc work style, or “winging it”.

One of the aims of introducing technology to assist coordination is to reduce some of the overhead of the operating logic and communication of the functional system. A common problem is that this requires some extra work by the users in coding and entering extra information in the computer system, which is often done reluctantly, or missed if optional, harming the effectiveness of the system. Also the introducing of a computerised network, replacing actual interpersonal interaction can have the harmful effect of reducing the

opportunities for repair work to be carried out or updates to context or shared understanding to be made (Rogers, 1993).

Cooperation involves something more than just coordination. It describes the fact that the activities being carried out by people share a related purpose. This purpose can be anything, but the individuals involved are performing activities that are somehow related, in their ultimate outcomes or their process.

Cooperative work can be defined as work that is “accomplished by the division of labour among participants, as an activity where each person is responsible for a portion of the problem solving” (Roschelle & Teasley, 1995, p.71). The work can be split, divided hierarchically into independent subtasks, carried out individually and later combined to solve a problem (Dillenbourg *et al.*, 1995).

Cooperation, in the CSCW sense can often be the process of managing units of work which are carried out individually, whereas collaboration tends to be a process of more than one person working on the same problem at the same time.

Collaboration, like cooperation, involves more than just coordination. It also requires that participants share a related goal. However, it involves more integration and inter-dependence. The difference between collaboration and cooperation is that the collaborating participants are working closely together on the same task, process or piece of work. They are partaking in a “mutual engagement of participants in a coordinated effort to solve the problem together” (Roschelle & Teasley, 1995, p.71). In collaboration, the work is being performed either simultaneously by more than one person, or divided into heterarchically related and intertwined layers (Dillenbourg *et al.*, 1995).

Examples of collaborative activities include meetings, decision-making, learning and content creation (Sharp *et al.*, 2007)

Furthermore, the temporal relation of activities has an impact on whether a process is described as coordinated, cooperative or collaborative. Coordination can be asynchronous, with separate events happening at any time. The using of the office stapler at one moment does not affect its use at another moment unless these periods overlap, or the stapler runs out of staples. In the case that two people wish to use the stapler at the same time, some synchronous coordination must be employed. Cooperation can be synchronous or asynchronous, i.e. sub-tasks can be completed at the same time by different people or at different times, perhaps one after the other if the starting of one task depends on the completion or output of another.

Collaboration can also be synchronous or asynchronous, but it is most typically synchronous. This is because collaboration most typically occurs in a real-time scenario, either face-to-face or using some remote collaboration tools, such as video conferencing. This facilitates the dense inter-twining of the tasks, references and processes which defines collaborative work through rapid feedback and swift building of concepts, whilst the task is the shared focus of the participants' attention. Asynchronous collaboration (for example, working together on a problem using email) is typically less effective than synchronous collaboration due to the delay in feedback and the work necessary to re-enter the conceptual framework repeatedly, and can lead to misunderstandings and ambiguity through the hindering of monitoring and repair work typically performed in collaborative conversation and working with shared references.

2.2.3 Shared References

In cooperative or collaborative work conversation is typically a main method by which information is shared. The approach of conversation analysis reveals how conversation is governed by many rules (Sacks *et al.*, 1978). For example, utterances between two people typically occur in 'adjacency pairs' whereby each phrase is acknowledged or responded to (Schegloff & Sacks, 1973). Other rules guide when one person should start or stop speaking. Guided by these rules, conversation can happen whereby information is communicated, discussions occur, new ideas are formed or feelings expressed. When comprehension breaks down on one or both sides of the conversation, an explicit question can be raised or a puzzled or frowning look can express the need for elucidation (Schegloff, 1981).

When enough communication has occurred, it can be said that the members of the conversation have built a shared understanding or common ground upon which further concepts can be formed, or verbal abbreviations can be used (such as saying 'it' to implicitly refer to an object already mentioned.) Common ground refers to mutual knowledge, attitudes and goals which are held by members of an interaction (Clark & Marshall, 1981; Clark & Wilkes-Gibbs, 1986). The coding scheme by which these concepts are represented can be formal or spontaneous. New 'contributions' (Clark & Schaefer, 1989) are introduced to the conversation and then 'grounded' by indications of acceptance such as simply saying "okay" or by further sequences of clarification (Jefferson, 1972; Sacks, Schegloff, & Jefferson, 1974). Thus, grounding describes the interactive process by which people exchange evidence about their

understanding over the course of a conversation, as the exploration and affirmation of common ground continues (Clark & Brennan, 1991).

Common ground allows more efficient communication through heuristic judgments and the use of shortened conversational phrases. Common ground can be assumed prior to an interaction if they are members of the same group or population (e.g., Fussell & Krauss, 1992; Isaacs & Clark, 1987). For example, medical doctors will assume a degree of overlapping knowledge that allows the use of precise terminology. The interlocutors can then extend or change common ground as is befitting their needs.

If the people in the conversation are in the same physical setting, then physical cues can also be used as common ground (Clark & Marshall, 1981). Being physically co-present enables sound, touch, smell etc. to be utilized, but most importantly, it allows visual sources to be used as a resource for grounding. When we don't know the name for something, we can just point at it. We can draw shapes in the air, or use our hands to indicate the size of something. There is a whole library of common gestures that can be used with members of a common cultural background. The ability to visually distinguish things is important in problem solving as it allows us to work with objects / icons / concepts when they are in the middle-stages of generation, and are somewhat ambiguous and nameless. Because interaction around digital tabletop surfaces allows for full face-to-face expression and range of movement, without visual obscurities, it is thought that they facilitate the widest possible range of expressions of common ground and grounding methods. This shared visual space can facilitate task awareness and conversational grounding (Daly-Jones *et al.*, 1998) and the bandwidth of the shared visual space is related to the

effectiveness of grounding activities and the overall efficiency of collaborative tasks (in a bicycle repair task with an instructor – Fussell, Kraut, & Siegel, 2000).

Oftentimes communication can become more non-verbal as coordination continues and people become more comfortable, familiar and ‘attuned’ to each others gestures and set of active shared conventions/representations, or can be formally constructed to take the place of speech when it is impractical to talk, such as conducting orchestras and marshalling planes on runways. (Some non-verbal cues are even translated into text when visual bandwidth is reduced, e.g. “LOL”).

If communication breaks down at some point, it can be due to ambiguity or confusion over indexical references. For example, in the course of a conversation one person may use the word ‘it’ but the other person may need to ask, “What do you mean by *it*?” This is a facet of grounding known as repair activity (Sacks *et al.*, 1978; Suchman, 1987). Repair activity is a common process as members of a conversation become aligned in their understanding of shared concepts.

Grounding conversations is important in collaborative work, as the individuals must work on a shared understanding of the problem and its related concepts. In understanding how to design and evaluate digital tabletop systems, we must be aware of the work of conversational grounding, and consider how to support clear and direct communication and deictic referencing.

2.2.4 Functional Systems and Context

Collaboration is a contextually situated activity. Knowledge of the process and the significance of objects amongst the collaborators for a given context and

situation can be thought of as distributed cognition (Hutchins, 1995). For example, an individual goes to give a report to someone else, but finds their desk empty, so leaves the paper on their keyboard. When the other person returns, they will find the report and use it. Here, there are aspects of cognition distributed between actors and across time in a situated space. The significance of leaving the report on the keyboard, knowing that it will be seen and the reason for its being there apprehended (perhaps the other person had requested it or was otherwise expecting to receive it). This is an example of a *functional system* (Flor & Hutchins, 1992). Changes in context or objects may alter the validity of the actions. For example, if the document is highly sensitive the person may choose to come back later rather than leave it unattended, or if the other person is away sick the report may be delivered to somebody else instead. There are assumptions in place, and a mutual expectation of certain behaviours that allow this functional system to operate, for example, the person leaving the report will assume that, since the other person was expecting the report they will not throw it away when they discover it.

Modern theories such as Distributed Cognition take functional systems as the basis of analysis and apply a cognitive framework on top. The cognitive approach allows for studying the effect of distributing knowledge across the members of the group and represented in various states across external media, i.e. paper, computer displays, etc. (Rogers and Ellis, 1994). Distributed Cognition also highlights the importance of situations where the collective understanding of these representations breaks down, and the significance of recovering from these situations for the learning and sharing of knowledge between the group.

In relation to digital tabletop systems, designers and researchers must be sensitive to the ways in which groups use and share information and cognitive load across the group and representations on the screen, around the table etc.

2.2.5 Collaboration on Tabletops

Collaboration and cooperation are defined by Bannon & Schmidt (1989) as two or more people working to create a common outcome. Rochelle & Teasley (1995) and Dillenbourg (1999) describe the difference between the two terms as: cooperation is the *horizontal* division of work into sub-tasks that are completed individually; collaboration is the *vertical* division of work, where all members of the group do work synchronously. Rochelle & Teasley state that a key process in collaboration is the creation of a shared conception of a problem (p. 70). It has been suggested that collaboration can be better than solo work for learning and problem solving. Chickering & Gamson, (1987) state that:

"Learning is enhanced when it is more like a team effort than a solo race. Good learning, like good work, is collaborative and social, not competitive and isolated. Working with others often increases involvement in learning. Sharing one's own ideas and responding to others' reactions sharpens thinking and deepens understanding."

Thus, collaboration can include additional process such as externalization and elicitation (Dillenbourg, 1999). Although this, along with other procedural overheads such as managing the group activities, adds to the total amount of work necessary per group member, it is thought that the extra effort is more than offset by the improvement in outcome. Krajcik & Czerniak (2007) agree,

stating that collaboration almost always works better than individual learning, citing the following reasons:

- Multiple zones of proximal development are created among students that help scaffold learning
- It positively affects achievement, problem solving, and understanding.
- The cognitive load is spread among students.
- It promotes autonomous, motivated learning.
- Anxiety about learning is reduced.
- Groups traditionally left behind in science are more likely to be included.
- Real life skills are developed.

This reflects some of the benefits of collaborative work that proponents of interactive tabletop technologies espouse. If one assumes that interactive tabletops do promote more effective collaboration then this could be due to the affordances it offers such as a large persistent surface for the creation of iconic representations or text, which can serve to spread cognitive load between participants and to relieve the strain on working memory through supporting external cognition. Importantly, it allows the full bandwidth of verbal and non-verbal communication to be used.

In designing software for collaborative scenarios we have to consider the context of its use. Designing applications that are sensitive to the issues arising from supporting close collaboration with technology can be a challenge. The

tabletop designer must take into account how users interact with the tabletop individually, with each other, and in pairs or groups simultaneously, in synchronous and asynchronous fashions.

The potential for collaborative interaction at a tabletop has long been of interest to researchers. A regular, non-digital tabletop is the prototypical setting for collaboration – “let’s get around a table and sort this out.” Kruger *et al.* (2002) discuss several properties of tabletops which relate positively to collaborative activities: social affordance, large horizontal space for physical support of objects and the widely understood social protocols surrounding use of tables. These factors all help reduce cognitive load, prevent conflict, maximize communication and enhance collaborative activities.

Jamil *et al.* (2012) discuss how the affordances of digital tabletops can support group interaction with schoolchildren in India. In particular, they describe how the children exhibited certain collaborative strategies and interaction techniques when performing learning activities at a digital tabletop (a custom-built FTIR table). As Jamil *et al.* note, it is important to observe the natural ways in which the children interacted with the tabletop before imposing restrictions, or enforcing particular interaction styles, in order to reduce the likelihood of reducing natural expression and effective collaboration styles.

The possibility of combining familiar ways of working together at tabletops with digital capabilities is enticing. However, care must be taken to note the potential drawbacks of providing a multi-touch tabletop application for collaborative activities. The capability of such devices to support multiple simultaneous inputs can lead to a *reduction* in collaborative activity as users can work in

parallel, and can increase the time it takes to complete a task as leadership roles are not defined up-front (Marshall *et al.*, 2008; Hornecker *et al.*, 2007).

As Jamil *et al.* (2010) found, teenagers using an interactive tabletop compared to a non-interactive one, exhibited different conversational styles. They suggested that the different methods of interaction, and effects of the interface, resulted in these differences. They found that users around the non-digital tabletop made more task-oriented utterances in conversation, possibly because the interface itself did not require discussion (unlike the digital tabletop). Indeed, the number of responses was higher with the non-digital tabletop, suggesting more collaboration. In the digital tabletop condition, users spent more time discussing how to use the tabletop.

This shouldn't be seen as damning for digital tabletops, however. Simply we must find what tasks they are better suited to. It may be that digital tabletops will be seen in the future as more useful for parallel tasks, and, of course, they will be suitable when dealing with digital artefacts. There are other important ways in which tasks can be collaboratively solved which do not depend on verbal utterances. The physical interactions and follow-through of actions can be equally important (Rogers and Lindley, 2004),

In fact, the importance of the interface was underlined in a later study with secondary school students from the UK by Jamil *et al.* (2011) where comparison in conversation type was made between two interactive tabletop modes and a non-interactive mode. The direct touch interactive mode was found to result in equal amounts of reflective, topic-based, and interdependence conversation as the non-digital tabletop, whereas the pantograph interaction-based interactive

mode had less of these types of utterances. Reflective and interdependent utterances in conversation are thought to be important in collaborative learning activities.

2.2.5.1 Awareness of Situation and of Others' Actions

In order to achieve effective cooperation or collaboration, people must be aware of certain things such as the availability of tools, the state of completion of other peoples' tasks or environmental factors (Pinelle *et al.*, 2003). Awareness can be defined as "an understanding of the activities of others, which provides a context for your own activity" (Dourish & Bellotti, 1992, pg.107). This is congruent with Dillenbourg *et al.*'s (1996) definition of collaboration as "a coordinated activity that is the result of a continued attempt to construct and maintain a *shared conception* of a problem."

Endsley (1995) used the term 'situational awareness' for people's mental models of complex, dynamic environments. Gutwin and Greenberg (1996) referred to 'workplace awareness' to describe the knowledge of the current state interactions within a workplace, rather than simply awareness of the physical workplace itself. Humans have a great ability to maintain peripheral awareness of many variables and subtly adapt their behaviour to take these factors into account.

Heath & Luff (2000), in their ethnographic study of public transport operators in London, found that work practices evolved naturally to rely on situational / workplace awareness to form very effective cooperative partnerships. For example, one worker, who was responsible for managing the movement of trains, was overheard by another worker to give an instruction relating to a

disruption of the running of trains. The other worker, who was responsible for supplying passenger information, was able to make an announcement before it was even possible for the first worker to give him an explicit instruction. This high degree of situational awareness, and the understanding of each other's roles and how they were inter-connected, is a common feature of effective cooperative and collaborative work.

Situational awareness is also important when giving instruction or engaging in 'repair activities' as discussed below. For communication to happen effectively between people the communicator must be continuously aware of factors about the communication partner such as whether they are ready for interaction or currently overloaded with other work (Orr, 1996). Dourish & Bellotti (1992) devised a video system, which enabled peripheral awareness of members of a team. This gave the affordance of 'shared feedback', which gave cues to events such as when someone completes a task, without the need for extra, explicit, actions. They concluded that knowing the state of certain things, e.g. what other members of the team were doing, their location, progress on task, emotional state etc. led to greater team effectiveness and sense of community.

In collaborative tasks using an interactive tabletop, participants are able to use peripheral awareness to monitor the action of others. Because they share a touch-based input surface, people's hand gestures give information about their actions (Rogers *et al.*, 2004), and through shared understanding of the common goal, about the upcoming intentions. This 'follow-through' of action followed by awareness in the other collaborators is allied by verbal and non-verbal communication such as eye contact, eye gaze, or simply saying "done" (Marshall

et al, 2007). Collaborators can even predict which actions a person intends to do through visual preparatory movement (Gutwin & Greenberg, 2002).

This high level of awareness and shared understanding about peoples' interactions leads to a smooth interplay of actions which is an indicator of the presence of awareness in a collaboration. In this case there is typically a high degree of non-verbal communication. The occurrence of clashes, collisions or communication breakdown can indicate a lack of awareness in the participants (Gutwin & Greenberg, 2002). This can impose a need for verbal communication in order to explicitly make corrections. Individuals in a collaborative group can enhance other's awareness of their actions by using verbal shadowing (Schmidt, 2002), exaggerated hand gestures (Heath *et al.*, 2002) or certain actions that signify something implicitly (Gutwin & Greenberg, 2002).

Hornecker *et al.* (2008) and Forlines *et al.* (2007) looked at how digital tabletops can increase workspace awareness of collaborators' actions compared to multiple mouse input. That is to say, even when absorbed in individual interactions, a user has greater awareness of what the other people around the tabletop are doing. This leads to more dense interaction, and this may be beneficial for some activities. In their study, Hornecker *et al.* conclude that the benefits of increased awareness may outweigh costs, such as social awkwardness such as if hands collide when reaching for the same on-screen object. They also found that touch-based interaction with tabletops promoted easier shifting between social roles by the group members.

Awareness can be compromised when using other methods of collaboration such as interactive whiteboards. The vertical orientation of the interactive

surface tends to lead to the formation of a different group dynamic, whereby one person primarily manages the interaction with the surface (the 'scribe') at any one time. This means a shift in awareness happens each time the scribe changes role from conversational member to note-taker (Rogers & Lindley, 2004).

High awareness and the ability to express through gesture, body language, and eye contact in addition to verbally means there are more 'entry points' to an interaction (Hornecker *et al.*, 2007). This also has the interesting effect of producing more equitable interaction, as Buisine *et al.* (2012), Marshall *et al.* (2008) and Wallace *et al.* (2013) found. This means that each user has a more equal proportion of the total number of interactions. This could potentially lead to better outcomes as more alternative viewpoints are shared and the possibility of one individual being overly dominant is reduced. If this does not occur, or if one partner dominates, the interaction is less successful (Driscoll, 1994; Hausfather, 1996). To quote Wallace *et al.*:

"The presence of digital tabletops led to improved performance... In particular, the digital tabletop supported a group's ability to prioritize information, to make comparisons between task data, and to form tableaux which embodied the group's working hypothesis. Our analysis also revealed correlations between equity of participation measures and group performance." (2013)

Collaborative interaction is inherently multi-modal, with speech, writing, pointing, eye contact and gestures all contributing to the wide bandwidth of communication. Tabletops support multimodal communication between co-

located users more successfully than technologies such as whiteboards or laptops (Rogers & Lindley, 2004; Piper & Hollan, 2009). Rogers & Lindley (2004), Ryall *et al.* (2006) and Kruger *et al.* (2002, 2003) have compared tabletop and whiteboards for collaborative activities and concluded that, except for presentations, whiteboards can hamper effectiveness due to social awkwardness and the tendency for one person to become dominant. Rogers & Lindley (2004) conclude that tabletops improve the quality of interactions by being more socially natural settings which foster better face-to-face collaboration, encourage more role changes, enhance awareness, and explore a wider variety of ideas.

Tang *et al.* (2006) concluded that collaboration over tabletops is dynamic, fluid, and stateless, therefore being difficult to operationalize. Hron *et al.* (2007) found that the use of content-specific graphical aids assisted the production of more coherent explanatory text (in a learning task) and improved individual levels of knowledge acquisition, compared to video work without a shared workspace.

2.2.6 Interruption and Recovery from Disturbance

With collaborative activities around tabletop computers, it is important to consider how interruptions in the flow of the activity might occur, both from internal and external sources. Of course, trying to keep interruptions from the software to a minimum should help the users to work more effectively, but during the application flow, how much are they being expected to keep in working memory? If the application requires the user to remember modal states and lots of information in order to complete their flow, they might forget

this stateful information if they are interrupted, for example by someone talking to them. This underlines the importance of communicating visually and clearly the current state of the system at all times.

The fact that collaboration is typically seen as something which occurs in a singular time and space is possibly due to the fact that participants must share mental and physical models, use implicit and explicit references and focus their attention on a single task. All of this requires work that must be repeated if an interruption occurs.

"Interruption of people is problematic because people have cognitive limitations that restrict their ability to work during interruptions."

– McFarlane, 1999.

Interruptions can have very severe consequences if they happen during critical stages of work. The pilots of an aircraft flying out of Detroit in 1988 were interrupted during their pre-flight checklist by an update from air traffic control. Failing to resume their checklist comprehensively following the interruption directly led to the crash that ensued. McFarlane postulates that there are seven possible cognitive, physical and social effects of interruption: change in activity, change in salience of memories, change in awareness, change in focus of attention, loss of wilful control over an activity, change in social relationship and transition between stages of a joint activity (1997).

When using technology, interruptions can come from outside sources, or from the technology itself, through poor interface design, or even from the user if they forget a command or intentionally stop to change perspective or take a

break. McFarlane (1999) states “interaction design affects people’s ability to successfully resume previously interrupted tasks”.

Again, designers and researchers interesting in tabletop systems should be aware of how interruption occurs in collaborative settings with digital tabletops. The working memory load of collaborative tasks can affect how easily individuals can recover from interruptions, whether it is to manage the technical aspects of the system or from external interruption. If possible, the tabletop interface should support the user in ‘re-playing’ the interactions that preceded the interruption in order to recover their cognitive state and continue work.

2.2.7 Reflection

Dewey (1933) described reflective thought as “active ... and careful consideration ... of knowledge in the light of grounds that support it and the further conclusions to which it tends”. This skill is purposeful and critical and does not come about without considerable effort. Brookfield (1988) points out how reflection centres around four main activities: analysing assumptions, contextual awareness, imaginative speculation and reflective scepticism.

Analysing assumptions is crucial in reflection on experience as one of the goals here is to restructure knowledge and integrate new experience with old.

Contextual awareness means considering the wider social and environmental issues at hand, to create an integrated understanding of how the phenomenon being reflected on fits in with greater schemes. Imaginative speculation is important to make inductive reasoning about the domain possible and to raise awareness of incomplete or inconsistent knowledge and to see multiple

perspectives. Reflective scepticism is a continuous process of critical thought that is carried out throughout the other three processes, where the person reflecting comes from a neutral or actively sceptical viewpoint. These processes lend themselves to being supported by interactive tabletop applications. This is partly due to the tabletop's lightweight interaction methods, such as gestures and direct manipulation of objects and the ability to simultaneously engage in high quality social interaction (Scott, Grant, & Mandryk, 2003). By high quality interaction is meant that collaborative dialogue is not hindered by strict turn-taking rules, and can be enriched by hand gestures and eye contact. By virtue of allowing the users to perform effective collaboration, high quality social interaction and make and manipulate digital objects, tabletop interaction environments may be able to more naturally support reflection on experience.

Hatton & Smith (1995) found that engaging with another person in a way that encourages talking, questioning, or confronting, helped the reflective process by placing the learner in a safe environment in which self-revelation can take place. This revelation can come about from Brookfield's reflective activities such as analysing assumptions or imaginative speculation which can lead to the formation of theories with greater explanatory power or which reveal underlying truths about the experience being reflected on. Although a person may be able to – through their own imagination – come up with scenarios that they can virtually 'test out' the theories they make while reflecting on their experience, this can be greatly enhanced by the involvement of a collaborator who can challenge and confront their assumptions and knowledge. A shared tabletop surface can be used by different individuals to make a case to others,

through several forms of evidence, such as text, photos or video. This may be particularly helpful if someone is resistant to change (Fleck, 2003).

Interactions with tabletop displays, such as Microsoft's Surface or MERL's DiamondTouch look promising as a way of supporting novel forms of reflection on experience. In particular, the shareable technology offers several advantages over traditional single user PCs. Firstly, working around a tabletop is instantly familiar, as this is the most common way collaboration occurs in non-digital domains. Secondly, a tabletop is a place to share and use objects, such as drawings, to augment conversation. Thirdly, objects can represent complex ideas, and persist visually, to create a form of external cognition (Scaife & Rogers, 1996), which can be leveraged to make reflective breakthroughs.

Tabletops are also able to offer effective support for reflective tasks due to being reality-based interfaces (Jacob *et al.*, 2008). Being able to create meaningful representations can increase understanding amongst the collaborators by the virtue of simply creating an explicit representation (Chi *et al.*, 1994; Chi, 1996). Modelling interaction based on physical behaviours from the real world and using direct input overlaid on the display space with gestures can make for an easily learned and lightweight interaction. Given that reflection is a demanding task, we propose that the more natural and lightweight the interface the better it will support reflection.

Technologies such as tabletops, which allows for high-bandwidth, naturalistic input, and can present a large amount of digital information, is well suited to supporting fluid interaction and reflection. For example, moving quickly through media, processing large amounts of information, being able to make

quick annotations and making copies. The ability to work as a group and make and mutate copies of information, to go backwards, and compare objects side-by-side, is something that is not as easy with physical media.

The property of an interaction, whereby the user is able to remain in this high-level mode of thought and move in and out of interaction between the computer and the social environment, has been called fluidity. It describes the property of an interaction between a user and a technology such that it supports the user staying at an unbroken creative state of mind and being able to think about complex or abstract problems without having their train of thought interrupted by low-level requirements of the interface, such as dialog boxes, or visual clutter (Guimbretière, 2002; Martinez Maldonado *et al.*, 2010). It is assumed that highly fluid novel forms of interaction are possible with interactive tabletops (Jacob *et al.*, 2008). Properties of interactive tabletops such as the direct manipulation of objects, the intuitive style of interaction and the visual persistence afforded by the large display area, all contribute to a reduced cognitive and working memory load. This can enhance initial usability and learnability and also enable interaction with the digital environment to be more flexible, facilitating reflective collaboration and social interaction with group members in the non-digital environment.

Sometimes the term fluidity has been used to refer to 'flow' where a person can extend their thoughts to the higher-order goals of a task, and where a subjective experience of ease and pleasure ensues when using a given interface (Csikszentmihalyi, 1991). It has also been expressed in terms of higher- and lower-order levels of cognition: where intermittent attention is supported

between interface and conversation whilst keeping the creative thoughts and expressions ‘flowing’ (Morris *et al.*, 2008).

Tasks and User Groups

The sort of high-level reflective activities I propose to support using tabletops are the types of discussion that can lead to synthesising and integrating new knowledge and deeper understanding in a given domain. In particular, the quality, or type of things discussed, such as whether the topic of discussed focuses on abstracting principles from data, critical statements, speculation and imagination and integrative statements. It has not been shown that existing task classification systems such as McGrath’s Task Circumplex (1984) can be applied to tabletop-supported tasks, however I have considered many possible tasks and user groups that could lend themselves to a tabletop application (such as in the Appendix section 12.1).

Fluidity – Cognitive Aspects of Reflection

To examine how users collaborate around interactive tabletops, I will focus on two particular behaviours: fluid interaction and reflection. The term ‘fluidity’ is used widely in HCI literature but is not well defined and has been used to mean many different properties of technologies, design and interactions. It describes the property of an interaction between a user and a technology such that it supports the user in staying in an unbroken creative state of mind and able to think about complex or abstract problems without having their train of thought interrupted by low-level requirements of the interface, such as dialog boxes, or visual clutter.

It is assumed that highly 'fluid' novel forms of interaction are possible with interactive tabletops (Jacob *et al.*, 2008). Properties of interactive tabletops such as the direct manipulation of objects on the surface, the intuitive style of interaction which can result from simulating the behaviour and appearance of digital objects based on the physical properties of real objects and the visual persistence afforded by the large display area, all contribute to a reduced cognitive and working memory load. This can enhance initial usability and learnability and also enable interaction with the digital environment to be more 'lightweight' and flexible, facilitating better collaboration and social interaction with group members in the non-digital environment.

Sometimes the term 'fluidity' has been used as a shorthand for 'flow' in the sense that the user can extend their thought to the higher-order goals of the task, and a subjective experience of ease and pleasure when using an interface (for a full definition of flow, see Csikszentmihalyi, 1991). The design principles suggested by Guimbretière (2002) are valuable constraints for improving interfaces, especially with post-WIMP technologies, but do not provide specific evaluative measures for interaction.

Design guidelines are also emerging which bear this support of lightweight interaction with the technology in collaborative settings, to help develop more fluid tabletop interfaces. For example, Scott *et al.* have produced a series of guidelines for designing tabletop interfaces (2003), where the concept of fluidity is expressed as a list of principles with a focus on lowering the cognitive overhead of making transitions from one representation to another, from group work to shared work or moving between activities. Isenberg *et al.* (2007) have noted that these guidelines can be expressed in the positive sense of supporting

high-level cognitive aspects of a task without forcing the user to deal with low-level objects.

An interface that facilitates a reduction in cognitive and working memory load makes these resources available for other processes. A key cognitive aspect of effective collaboration is reflection. This applies particularly to learning tasks – where existing information is synthesised into new knowledge, for example when data is analysed and a pattern describing its distribution is produced. As discussed below, reflection is supported if the user is able to change their intellectual perspective easily and start and stop their interaction with a tabletop in a lightweight and intuitive manner, i.e. fluidity supports reflection.

“Reflection is considered to be an important part of the learning process... especially for learning from experience, developing the skills of professional practice and for the development of meta-cognitive skills which are said to enhance learning.”

– Fleck, 2003, p.1

Dewey described reflection as an active thought process, provoked by uncertainty or difficulty, comprising “an act of searching, hunting, inquiring, to find material that will resolve doubt, settle and dispose of perplexity” (1993 p.12). Another way of describing reflection in terms of knowledge representation is that it is “a kind of problem solving involving the construction of an understanding and reframing of the situation to allow professionals to apply and develop their knowledge and skills.” (Fleck, 2003, p.1).

There is a growing emphasis on reflection as a critical part of learning which should be designed for in teaching at school and university levels (Boud, Keogh, & Walker, 1985; Moon, 1999), and Reinman (1999) has suggested that learning cannot take place without reflection. As Kolb (1984) suggests, reflection affords learners the opportunity to form abstract concepts from their experience, and, in turn, engage in active experimentation and guide further learning experiences. These abstract concepts are formed by thinking “for an extended time about a set of recent experiences looking to commonalities, differences and interrelations beyond their superficial elements” (Gustafson & Bennett, 2002). However, they note that this reflection is difficult to achieve in learners.

Hatton & Smith (1995) found that engaging with another person in a way that encourages talking with, questioning, or confronting, helped the reflective process by placing the learner in a safe environment in which self-revelation can take place. This is highly relevant to parts of the proposed research project as learning is often a collaborative process. The tabletop interface allows several forms of evidence to be displayed which can challenge a learner’s point-of-view and the collaborative processes of instruction through scaffolding of ideas can be enhanced by this visual persistence. This is particularly true if a learner is resistant to changing their way of thinking about things. Surbeck *et al.* (1991) suggest that there are three important levels of reflection: Reaction – which involves identifying a personal emotional aspect to the experience, Elaboration – which concerns the comparison of the reaction to other experiences, and Contemplation – which involves constructing insights and considering future goals. This inclusion of personal emotional response to experience as a guide for reflection is echoed by Boud *et al.* (1985) who describe reflection as “a term for

intellectual and affective activities of explaining experiences to get new understandings.”

Four activities are central to critical reflection (Brookfield, 1988):

Assumption analysis - This is the first step in the critical reflection process. It involves thinking in such a manner that it challenges our beliefs, values, cultural practices, and social structures in order to assess their impact on our daily proceedings.

Contextual awareness - Realizing that our assumptions are socially and personally created in a specific historical and cultural context.

Imaginative speculation - Imagining alternative ways of thinking about phenomena in order to provide an opportunity to challenge our prevailing ways of knowing and acting.

Reflective scepticism - Questioning of universal truth claims or unexamined patterns of interaction through the prior three activities - assumption analysis, contextual awareness, and imaginative speculation. It is the ability to think about a subject so that the available evidence from that subject's field is suspended or temporarily rejected in order to establish the truth or viability of a proposition or action.

Based on previous findings on the benefits of interactive tabletops, the facility to make direct manipulations of representations of data, the persistence of digital artefacts and the ease of collaboration should all support reflective tasks.

In order to measure reflection, researchers have investigated the materials used. Yinger & Clark (1981) suggest that reflection, when written down, is more powerful than other forms of recording. It may prove to be a requirement in

some contexts that a collaborative tabletop application should allow notes to be added to other media. Paper and pen journaling has also been studied by Moon (1999), McDonnell *et al.* (2002) and Loh *et al.* (1998). Fleck (2003) found that automatically captured images acted as a resource for grounding and structuring reflective conversations. She also found that “recording events using video might provide a more accurate picture [of events for reflection]”, (2006, p. 2.)

Video has also been used for reflection by McDonnell *et al.* (2002), Zuber-Skerritt (1984) and Hutchison & Bryson (1997). Smith *et al.* (2005) investigated using automatically logged data as a recording source for reflection. These records are assumed to assist in grounding reflective conversation, providing a referent and a persistent artefact (Clark & Brennan, 1991). Zuber-Skerritt also suggests that these records provide a baseline for reducing cognitive dissonance between experience and evidence and a means of gaining intersubjectivity and new perspectives – and that reflection is a mechanism for change in the practice of video self-confrontation.

Peer-collaborative reflection can support multiple points of view (Boud *et al.*, 1985) as peers will have to argue, critically promote, negotiate and integrate other’s opinions into their view (Dillenbourg, 1999). Mercer & Wegerif echo this, saying that the most productive talk between peers in terms of learning outcomes is ‘exploratory talk’ meaning to ‘engage critically but constructively with each other’s ideas’ (1998, p.85).

To summarise, reflection consists of:

- Restructuring and integration of knowledge;

- Raising awareness of: incomplete knowledge; inconsistent knowledge; assumptions and what is known; and
- Seeing multiple perspectives.

2.3 Fluidity

In considering which factors affect the success of system such as collaborative applications for tabletop computers, I have attempted to describe a term that is commonly used but rarely defined: fluidity. In attempting to describe what this term describes, I also became aware of the need for a template for thinking about how to support group goals. This seems important considering the interface differences of tabletops compared to traditional PCs, and the nature of supporting a group whose individuals may share different concepts of the shared goal, or even different goals.

Fluidity has been used to describe the various transitions that are needed to enable collaboration (Tang *et al.*, 2006) and the obstacles that can hinder interactions, such as dialog boxes popping up (Guimbretière, 2002) and as Isenberg *et al.* (2007) have noted that these guidelines can be expressed in the positive sense of supporting high-level cognitive aspects of a task without forcing the user to deal with low-level objects. The benefit of such fluidity of interaction is that users can bring more of their attention and creativity to bear on their ultimate goals, or other demands such as collaboration, leading to more productivity and higher quality work.

One approach to fluid interface design is in terms of reality- based interaction (Jacob *et al.*, 2008). This seeks to model real-world themes and to reduce the gap between a user's goals and the means of execution. The real-world themes

are naïve physics, body awareness, environmental awareness and social awareness. By designing interfaces, based on the rules of these dynamics, the need for low-level operational expertise is reduced, affording the user the opportunity to focus on higher-order goals and more focused creativity. Also, it should be easier for users to return to where they were previously when interrupted, as the cognitive effort of getting back into the framework of the interaction is reduced. This also affords the benefit of encouraging reflection and viewing the bigger picture for a fresh perspective or learning. As these interfaces provide more natural interaction it is also hypothesised that they will lead to better social interaction when working in groups.

It follows that multiple display and device systems should not be unnecessarily complicated, and should employ reality-based interaction where possible, except where certain explicit trade-offs are made to add further functionality. Jacob uses the analogy of the character Superman: when he is performing simple tasks he walks and talks like a regular human, but when the situation requires it he uses his powers to increase his efficiency in completing his task.

The concept of fluidity is appropriate for analysing the complex development of multi-user, multi-device interactions. One challenge is to provide a way for users to get the most out of the technology at novice and expert levels. Too little help or signposting and the novice cannot engage with the system: too much and the expert user becomes frustrated. Guimbretière argues that dialog boxes, tool selections, object handles etc. are “inevitable to provide complex functionality” (Guimbretière, 2002, p. 3). His FlowMenu (Guimbretière & Winograd, 2000) gives visual feedback without permanent menu bars or palettes by using a pen-addressed radial layout menu, which encircles the

pointer whenever the menu is summoned but also allows experts to use gestural memory without feedback.

However, collaboration is not governed solely by the quality of the interaction that the user has with the interface but also the interactions between the user and others, and other users and the interface. A successful collaborative task may depend on the ability of individuals to work singly in personal spaces while carefully choosing their interactions with the other users at various stages.

Given the intricacy of group interactions, another challenge is to design computer interfaces which can support them while being simple enough to use that all group members can contribute effectively.

As pointed out by Tan *et al.* (2008) there is a dearth of evaluation methods for collaborative environments. I have attempted to begin to form a framework for evaluating collaborative environments, initially by describing the key dimensions so other researchers can share the same language around collaborative systems. To this end I have described three concepts related to evaluating collaborative systems: the fluidity ratio, cognitive fluidity maps, and interaction matrices.

2.3.1 The Fluidity Ratio

The first heuristic, *the fluidity ratio*, is based on the idea of measuring interactions when moving between subjective states of involvement: our starting point is Heidegger's well-known concepts of readiness-to-hand and presence-at-hand (see Winograd & Flores, 1987). The canonical example of using a concrete tool such as a hammer exemplifies what it means to switch between 'present- at-hand' and 'ready-to-hand' depending on the user's

awareness of the hammer. When hammering away at a nail one is often not aware of the hammer as being distinct from one's own arm and hand or part of our 'totality of involvements'. The tool becomes an extension of ourselves in the expression of our task. In this state the hammer is ready-to-hand. However, should the hammer break or hit our thumb we would become aware of the interruption to our task and the hammer would become present- at-hand.

In terms of user interactions, we employ this idea to conceptualise when a user is interrupted in the flow of completing their task. *Higher-order* user actions are those directly related to dealing creatively with a task; those which are directed at dealing with the state of the computer are *lower- order*. That is to say that lower-order operations are where attention is focused on the tool, and higher-order operations are where attention is focused on the target of the tool.

Expressed as a ratio of higher- to lower-order action, fluidity is essentially the property of being in a higher cognitive state and focused on the task, not the tool. Thus:

$$fluidity = \frac{higher-order - lower-order}{total\ operations}$$

The key feature of fluidity is that it is a measure of the proportion of task-specific actions and cognition. For example, if a user is to draw a circle and label it with text, they might perform 15 operations dealing with low level aspects of the machine such as opening the program, selecting the appropriate view and palette, selecting the right tool, and changing to the text tool, and the operations which are related to the higher- order goal such as drawing the circle or typing the text would amount to two. This would give a fluidity score of $F = (2 - 15) / 17$.

Compare this to performing a similar task on a drawing surface such as Guimbretière's PostBrainstorm interface (2002). The lower-order task would be picking up the pen, but drawing the circle and writing the text would be done directly as two higher-order goal-centred operations, giving a fluidity score of $F=0.33$. Compared to the previous example the fluidity score F is large, and in a more positive direction, indicating that it leads to a more fluid interaction.

As well as comparing across interfaces, this heuristic is also intended to be applied across experience levels. Supposing that a new interface is highly reality-based then experience level should have less of an effect on the F score. Any difference in F could indicate that experienced users are employing shortcuts, which could indicate an area for further study.

When defining and analysing fluid human-computer interactions, therefore, it is important to take into account the users' level of expertise with the task and the technology. It may be possible to design interfaces that are fluid to use by experts for a task but not for novices (e.g. a games console). There is a distinction also between expertise at lower and higher levels of action. For example, being an expert typist may not automatically confer an advantage to a player in a strategy game if they are not also expert at the higher-level goals and conventions of the game. Conversely, an expert tennis player might be at a disadvantage in a game of Wii Tennis against someone who has more expertise in using the Nintendo WiiMote controller.

As the fluidity ratio makes clear, a lot of what system designers and evaluators refer to as a 'fluid interface' is one that supports direct manipulation. In this

regard, tabletops are well suited due to their high bandwidth of natural gestures and direct manual input.

2.3.2 Cognitive Fluidity Maps

Similarly to the discount usability method of cognitive walkthroughs, cognitive fluidity maps are intended as a heuristic for designers and evaluators of software to consider how costly an interface is from the point of view of the user. This second heuristic graphically projects *cognitive focus* over time in an interaction. The upper chart of the figure below shows an example of how an experienced user might interact with a complicated application like AutoCAD. After launching the application the user can begin outlining whilst in a high-order cognitive state and considering their design goals. Next the user has to specify a certain variable and a specific dialogue must be sought where the user can input a variable e.g. wall thickness, or material type. Because the user is experienced and knows what to expect they can interact smoothly and without feedback or cogitation. Like Jacob's Superman the architect must make a small but useful interruption to their flow to make an explicit input.

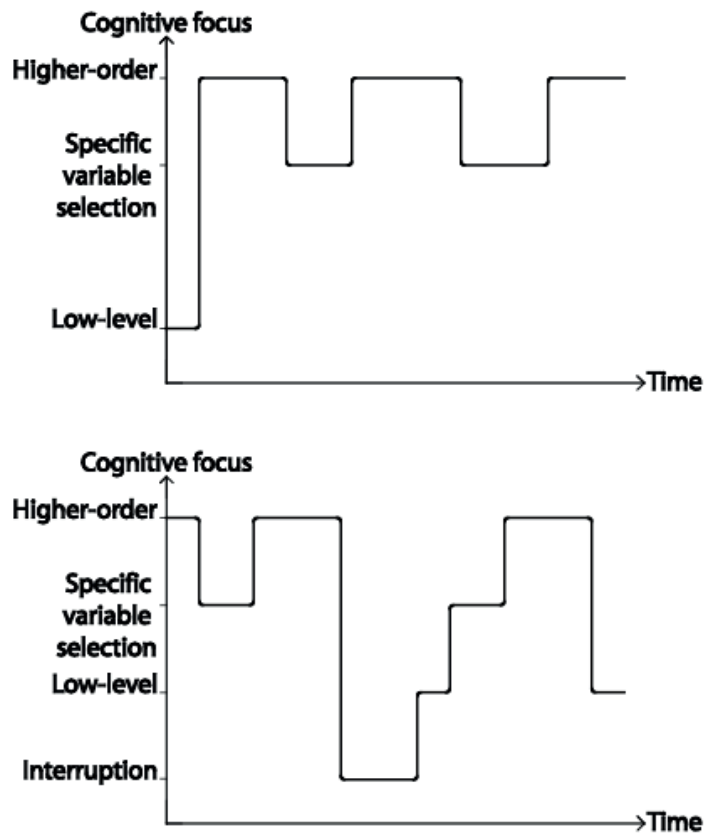


Figure 2.3: *Cognitive focus* over time in an interaction for (top) an experienced user and (bottom) during an interruption.

In the lower of the above figures, the user is interrupted during their interaction. The diagram shows how recovering from an interruption is costly as the user has to reframe themselves and remember what state the system was in before their interruption. Specifically, it describes a scenario where an individual is sharing photos with someone else using a tabletop display such as a Microsoft Surface with an interruption in the middle of the task. The figure is intended to highlight the difference between the users' experience of interacting with the table at times when low-level objects must be dealt with, such as waiting for data transfer or resuming the machine after it goes into standby during the interruption, and being able to operate on the higher-order goals of the task such as the actual photo sharing and discussion.

Following the interruption and resuming the machine from its standby state, a short period of time is spent by both users looking back over the photos in the stack. This is an example of how the user experience can be ‘buffered’ when moving back into an interaction, whereby remembering the state of the interface before the interruption and the position of photos relative to each other can aid the users’ memories and help in resuming the conversational thread. This could be enhanced further by, for example, replaying recorded audio from before the interruption to assist recollection.

2.3.3 Interactions ‘Inside’ and ‘Outside’ the Interface

Our third heuristic, *interaction matrices*, describes the interactions between groups of users with various interfaces. Supporting a collaborative design task requires the ability to move from working one-on-one with the computer, to social interaction, and multi-user interaction with the interface. In this context, fluidity impacts on the quality of an interaction that extends beyond the user-interface, as the properties of interaction ‘inside the interface’ can have an effect on social interactions ‘outside’, collaboration and the flow of ideas. Thus a user who is experiencing a fluid interaction with an interface will find it easier to take part in the social level of interaction, theoretically leading to better collaboration.

The figure below depicts several modes of interaction using a shorthand notation, or interaction matrix, taking the form {(‘outside’ interactions):(interface interactions)}. Situation ‘A’ is the simplest: one user and one interface are having one interaction {1:1}. In ‘B’ there are three users all interacting with both the interface and each other. The dotted lines on the

interface are meant to denote that there are different ways to divide the work area. All three users could be sharing the one interface together $\{(3*3):1\}$ or they could be working in separate spaces and sharing between each others' spaces $\{(3*3):(3*3)\}$, or simply working on their private spaces alone $\{(3*3):(1*3)\}$. In 'C' the users are interacting with each other but one user is mainly interacting with the interface.

Situation 'D' is a special situation where an expert user is interacting with the interface in a way the other group cannot and the output of this interaction is used by the group $\{(3*3):1:1\}$, such as when using a facilitator.

The interaction matrices can be used to describe how different user / interface combinations can lead to different design goals and expectations about fluidity. By separating the interaction matrices inside and outside the interface a clearer understanding can be reached of the true nature of interaction occurring. All these situations have different modes of interaction, but a fluid interaction between the user and the interface always benefits the entire goal, whether the user is in a group, alone, novice or expert. In 'D' the user is required to be highly expert as creating real-time visualisations of discussions is a complicated task. However, in 'B' simpler interface actions should be used to ensure all users have a similar level of control. Also, the interface should avoid dialog boxes, as it may be unclear which user it corresponds to. In 'A' the user can be novice or expert, depending on their level of experience and the necessity for complex 'superpower' operations. 'C' is in-between as the main user can fall on a range of expertise but other users may wish to input directly.

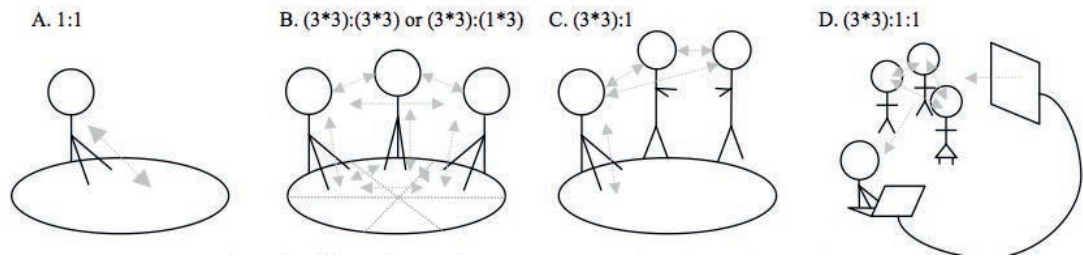


Figure 2.4: 4 examples of interaction matrices describing various arrangements of collaborative interaction around groupware.

2.3.4 Using the Fluidity Heuristics

Our fluidity heuristics are intended to assist both in the design and evaluation of interfaces and the various types of interactions, and group modes, by expressing different aspects of the fluidity of these interactions. The ready-presence ratio is intended to focus the designer on the way a user experiences readiness-to-hand, when focused on the higher-order goals of the task, and presence-at-hand – seeing the user and the tool (interface) separately. This heuristic can be used in tandem with the guidelines produced by other authors (e.g. Guimbretière, 2002; Scott *et al.*, 2003) to assist understanding of users' shifts in conscious awareness at key points. It assists in evaluation of the overall interaction quality and in comparing across interfaces or user experience levels.

The cognitive focus map can help in highlighting the transitions between users' states of awareness and 'presence' in the interaction, to help identify key areas in the design of the interface to enhance the user experience. The area under the graph also gives an evaluative indication of the overall fluidity of the interface, where a larger area indicates greater time spent in goal-focused states of mind. By adjusting for the total length of time of the interaction, it could be possible to analyse interactions in a way that is less skewed by experience level, in terms of dealing with dialog boxes etc., than the ready- presence ratio.

The interaction matrices heuristic can be useful in designing an interface by highlighting the ways that groups and single users can interact with it and with each other. By separating the interactions inside and outside of the interface it can be seen where design goals, such as removing visual clutter, will be most effective. It also provides a shorthand way of expressing specific interaction modes to help facilitate discussion and evaluation.

To illustrate how these heuristics can be used together to analyse how fluid the interactions are for users moving between displays consider the scenario of how scheduling work meetings could be enhanced through having a system of shared and personal displays. People in organisations use shared software calendars to arrange projects, meetings and schedules of work. However, it can be very time consuming to arrange a meeting, especially when it depends on email response. If a shared calendar application was made available whereby a large touchscreen could display an overall work schedule (i.e. a Gantt chart), representatives from each team could work either on the overview schedule or on small tablet or handheld devices to make fine-scale adjustments or to rearrange outside commitments around the emerging work schedule. The application could be analysed by using the three heuristics above. The interaction matrices would help in describing the different permutations of interaction possible in this arrangement, i.e. whether the users are all interacting with the large screen, their small screens or any combination between. This could assist a designer focus their methods for moving data between screens at the most appropriate times.

The fluidity of the interaction could be assessed for each individual user using the ready-presence ratio. This would give an impression of how different styles

of interface would support or hinder fluid interaction for any given situation. For example, when working on a small personal screen the user may have to make more low-level actions due to the size constraint of the interface, but this may lead to more rapid progression of the overall goal of organisation on the main chart.

The cognitive focus maps can be used to analyse the interaction over time and to bring attention to key moments, such as when a user switches between working in a shared area to a private area, or to help design ways for users to collaborate or resume work after an interruption. Explicitly considering where the user is focusing their attention at certain points can help the interface designer support key actions.

One problem, which may arise when collaboratively creating schedules, is that a clash may arise. Being able to work on their own sub-schedules individually, the team members involved can work in parallel to make fine adjustments and compromise to make the overall schedule work, and this could be expressed in an interaction matrix. Key points in this interaction would be the identifying of the clash on the main screen. Then the users would have to use the interface to edit their schedules individually and then return their change to the main schedule. How this is accomplished through interface design choices can be readily assessed using the ready-presence ratio and cognitive focus maps. Experimental studies could then be performed on different interface prototypes to evaluate their fluidity.

We propose that in order for groups to effectively utilise multiple displays by switching work between screens, interfaces and interaction styles and be able

to do so without interrupting the flow of their on-going tasks, the interactions have to be fluid. However, fluidity can be a nebulous term that is difficult to define. These three heuristics are intended to aid in the analysis of interface and task interactions, which can provide an indication of fluidity and clarify the processes involved. In so doing, they can highlight how to design for users so they can easily transition between multiple interfaces, tasks and conversation whilst keeping their creative thoughts and expressions 'flowing'.

2.3.5 Seamless vs. Seamful Interface Elements

Moving between individual, loosely-coupled work and synchronous, shared, tightly-coupled work can be achieved seamlessly using a large tabletop surface. However, when considering the benefits of creating a reflective process for collaborative work, it may behove the designer to consider these changes in collaborative style, or particularly significant moments in a workflow, as being significant in a particular way. This may mean that it is beneficial to enhance the seams of the interaction, to slow the user down so that they have a natural moment to reflect, to consider various levels of the problem, and to provide feedback about their progress.

It is commonly thought that making interactions as 'seamless' as possible is a virtue, however it is best to consider whether or not there is an opportunity to provide greater clarity and quality of information to the user, and the afford them the chance to reflect on the problem, on their behaviour, and to alter their interaction and collaboration style.

2.4 Tabletop Applications

This section on tabletop applications is a starting point for discussing which categories of human activity are suitable for support through a technology intervention such as a digital tabletop system.

Given the above factors, and the intention to design successful tabletop applications which support collaborative activity in an in-the-wild setting, what is an appropriate activity to support? As Bill Buxton said: “Everything is best for something and worst for something else. The trick is knowing what is what, for what, when, for whom, where, and most importantly, why.”² This research aims to contribute to answering these questions. One way of understanding the potential of the technology is to consider which tasks it could be applied to.

Choosing the right kind of applications for tabletops is crucial. It is possible to envisage many exciting real-world applications of tabletops. To date, tabletops have been used as a technology to support various collocated activities, including games and photo sorting (Rogers *et al.*, 2006). Applications have been created for the purposes of problem solving and learning (e.g. Piper *et al.*, 2006; Rick and Rogers, 2008). The process of choosing which applications to prototype for this course of research required extensive research, ideation, and evaluation of potential alternatives. Alternatives were investigated and discarded if they did not appear to offer the opportunity to create a system

² <http://www.billbuxton.com/multitouchOverview.html> accessed 19th December 2013.

which not only added value to real-world problem, but also as a platform for investigating issues around successful tabletop system design.

2.4.1 Evolution of Interfaces

Tabletop interfaces are an emerging class of interface with less in terms of historical context and expectation compared to traditional PC interfaces. They have also been found to be quite sensitive to small changes: “Overall, our experiences in designing and evaluating educational tabletop groupware indicate that relatively small UI variations, such as the modality or privacy of feedback, the layout of objects on the shared surface, or the presence of explicit awareness information, can produce observable impacts on students’ team work styles.” (Morris *et al.* 2006)



In a 2008 conference presentation "Predicting the Past," August de los Reyes, a Principal User Experience Director of Surface Computing at Microsoft described the NUI as the next evolutionary phase following the shift from the command-line interface (CLI) to the graphical user interface (GUI).



Figure 2.5: Interface Currents interface concept.

Several researchers have engaged with the challenges of designing for tabletops. For example, the support of simultaneous input can lead to problems in the sharing of common controls (Scott *et al.*, 2003), the feedback on users' actions (Tang *et al.*, 2006), the obstruction of viewing areas (Tse *et al.*, 2004), the visibility and ability to reach distant areas of large tabletops (Ryall *et al.*, 2004), the orientation and sharing of on-screen artefacts (Liu *et al.*, 2006), and managing the division of the tabletop into territories (Scott *et al.*, 2004). Although these issues have been addressed in creative ways, they sometimes are approached with a limited focus of matching the usability of personal computers. The unique affordances of tabletops can best be utilised by choosing activities which naturally fit their properties, rather than attempting to bring existing productivity tasks to them and converting interfaces.

2.4.2 Design Principles for Tabletop Systems

Gutwin *et al.* (2006) and Scott *et al.* (2003) have suggested design principles for collaborative tabletop applications. Scott *et al.*'s (2003) guidelines are:

- Supporting interpersonal interaction: The system should not cause conversation or visual breakdowns while the users are interacting. Natural interaction can also be supported with an appropriate and friendly physical design for the table.
- Supporting fluid transition between activities: This can be in terms of software tools, or hardware/software tools as in switching between using a physical keyboard and a stylus.
- Supporting transitions between personal and group work: Dividing the table space in personal and public areas is suggested as a way to support this.
- Supporting transitions between tabletop collaboration and external work: Work generated externally should be easy to incorporate in the tabletop environment and vice versa.
- Supporting the use of physical objects: Physical objects include pen, paper and/or tangible objects augmented with digital data.
- Providing shared access to physical and digital objects: Shared access to physical and digital objects should be provided where it helps in maintaining group focus and facilitates awareness.

- Form and configuration: Consideration should be paid to the appropriate arrangement of users and the table shape and size, in relation to the task at hand.
- Supporting simultaneous user actions: Parallel interaction should be allowed by all users, rather than restricting access to one user at a time.

Morris (2006) provides more low-level recommendations:

- Regions: Provide a central area for sharing resources, visually distinguish different tabletop regions, place user controls on the table edges, and allow for structuring the space like providing regions for trash.
- Clutter reduction: Consider the use of individual targeted audio as an alternative to visual representations when appropriate, and provide personal storage areas that can be closed and restored in a fluid manner.
- Access permissions: Provide means for fluidly controlling the access rights of documents, and if possible make these access rights visible to increase awareness.
- Group dynamics: Provide private and public, audio and visual feedback to increase awareness and regulate participation levels, consider the location of controls as this also has an effect on participation, enforce a structure on the interaction as this can help users with special needs, and prevent individual users from executing global level actions that affects others.

- Work style: Provide private audio feedback to help facilitate smooth transitions between tightly and loosely coupled activities, and provide global controls that can only be executed collaboratively to increase team spirit.
- Usability: Focus on design issues that are related to promoting effective collaboration rather than speed and efficiency.

Wallace & Scott (2008) had the most abstract reflection on tabletop design, instead focusing mainly on external factors and how they can inform the design of tabletop software. Important factors included social and cultural perception, activity type and duration, environmental aspects and the underlying goals. This essentially boiled down to who, what, when, where, and why.

They note that the primary effect these considerations might have is on the interface complexity. Aesthetic design and ergonomic factors are taken into consideration, along with connectedness and the wider device ecosystem. The potential for making embarrassing mistakes when using a public technology is noted and they recommend designing to avoid this, as opposed to private devices, where this is less of a concern. The degree of sophistication of the interface can depend on the expertise of the intended user population. Similarly, ergonomic decision can reflect the context – for example a classroom will likely require a different layout than a café.

2.5 Making Sense of Complexity

When we consider designing for contexts outside of the controlled conditions of the lab, complexity becomes an issue. As mentioned, designing for multiple users is a challenge because the combination of ways in which the members of the group can interact with each other and the interface increases exponentially.

Classical HCI approaches have tried to make interactions with software as easy to model as possible. However, the real world, and interacting with the public, is a complex system.

The Cynefin model (Snowden, 2000) is a framework for understanding systems along different dimensions of complexity. There are simple (categorical), complicated, complex, and chaotic systems. These represent four categories of systems in increasing order of difficult to model. In a simple model, A leads to B leads to C. In a complex model, which is a common system of business, complicated problem spaces are mapped out according to logical relationships, where A leads to B if certain conditions are met, and A leads to C if certain other conditions are met.

I suggest that HCI in the tradition of cognitive modelling is of the complicated type, where describing how a system moves from one state to another is attempted through definite rules. However, systems in the wild are more like the third category – complex. Here, there is no definite relationship between states A, B, or C. Rather; the conditions are more likely change in a probabilistic fashion. The problem space can be conceptualised as having areas of different densities, with drivers and dampers describing the potential paths through it, but with innumerable factors acting on it. Essentially, the system is too complex

to model in a deterministic fashion, but the important factors can be described as can the magnitude of their effect.

The last category is chaotic, where there is essentially no relationship between the different states. No prediction can be made as to how the system moves from state to state.

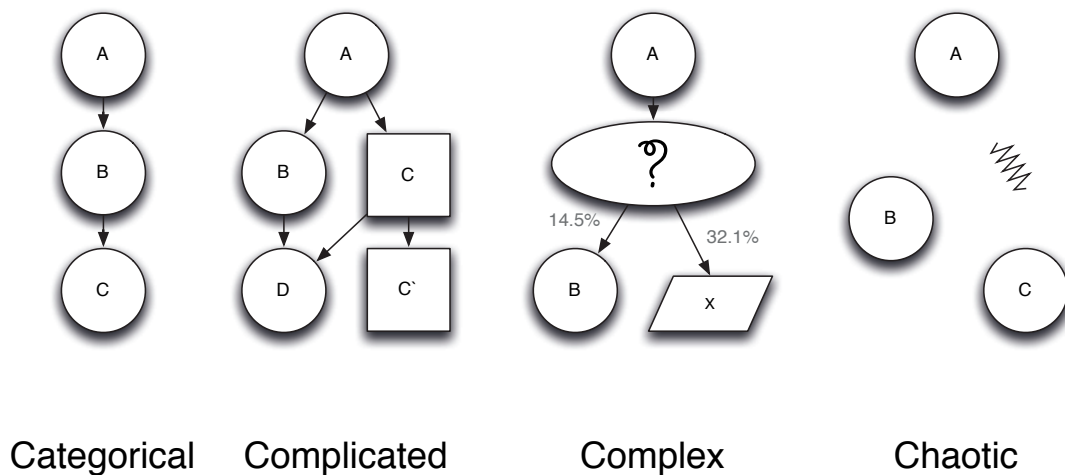


Figure 2.6: An illustration of the four categories of the Cynefin model

In order to design successfully in a complex problem space, a portfolio of multiple alternative solutions must be attempted and then observed to learn from the feedback of their introduction (c.f. Dow *et al.*, 2010; Hartmann *et al.*, 2008). In order to reduce waste, it is best to use the most easily constructed and cheapest representations to explore the early possibilities. This is the essence of 'lean' and it is a fundamental factor of the Lean Observe-Build approach. This is the approach I recommend for designing tabletop systems, owing to their high degree of complexity, especially in terms of the subtle social interactions.

- Design *in situ* in order to understand the environment and how the proposed solution will affect it.

- Work in cross-functional teams in order to ensure that the ways in which a potential solution will affect different critical factors will be understood.
- Start with low-fidelity representations of the solutions in order to reduce time spent producing alternatives that might be thrown away.
- However, do produce physical representations, not least in order to have something for the designer and other actors in the system to react to.

Steven Dow, HCI researcher at Stanford, suggests that prototyping gives you more to react to and compare with. This lets you understand the balances and trade-offs of different design alternatives more effectively. In his study alongside his Stanford colleagues (2010), they found that parallel prototyping, where creators made multiple prototypes before receiving feedback, resulted in better and more diverse design results. This is discussed in greater detail in Chapter 4.

3 Literature Review – In the Wild Studies with Tabletops

This chapter describes studies that focus on evaluating ‘in-the-wild’ tabletop systems and their use by members of the public in a naturalistic setting. As opposed to the lab-based studies on tabletops, these studies reveal a wider variety of unexpected results. The importance of in-the-wild studies and ethnographic-style observations are discussed with reference to providing rich contextual descriptions and aiding discovery of problems with interface design which are hard to predict before deployment.

3.1 Introduction

Large-scale interactive displays have become a more common sight in our public spaces. Whether it is tabletops in museums or large wall displays in public plazas and the facades of buildings, the potential of eye-catching, rich visual interactive information for education and entertainment is growing. The visual presence and the novelty of the interaction promote active engagement with the content, but how can we move beyond simple playful interaction.

Designing for such instances is a challenge given the breadth and diversity of potential users in public spaces, many of which will be focused on other immediate goals and social interactions. The interaction of the display within the context of its surroundings must also be taken into account. What is the scope for designing effective interfaces that can shape people’s experiences of

these public spaces and what methods of evaluation are suitable in these scenarios?

The scope of in-the-wild research is characterised by evaluating existing practices and evaluating new technologies *in situ* (Crabtree *et al.*, 2013). The experiences created by introducing technological interventions to these real-world settings are not always intended to meet a particular user need. The designers may seek to make technology work in concert with existing behaviours, or to disrupt behaviour, by augmenting people, places, and processes. The importance of conducting research in this way is to ensure that the possibilities of new technology are realised to advance human values and not diminish them.

Interactive public displays have been studied by several researchers (Dalsgaard & Halskov, 2010; Strupek, 2006; Valkanova *et al.*, 2010) and in particular focusing on the social interactions around these displays (Brignull & Rogers, 2003; Hinrichs *et al.*, 2008; Hornecker *et al.*, 2007; Hornecker, 2008; Jacucci *et al.*, 2010; Peltonen *et al.*, 2008). However, despite the valuable insights from these studies the field of in-the-wild tabletop research is still in its infancy. The aim of this thesis is to provide a condensed form of some findings resolved towards more effective future design and deployment of tabletops in public spaces.

As Schöning *et al.* (2009) state: “Let non-experts explore your systems” and “Do less lab studies and give the technology to users and test it in the wild”. This sentiment is echoed by Rogers, (2011), who reminds us that although lab studies give a great degree of control and reduce potential confounds, the

generalizability of their findings is equally limited and the in-the-wild application of theories derived in the lab can often lead to disappointment.

Naturalistic research studies of new technologies, often called ‘in-the-wild’ studies, can be expensive and challenging to carry out. Studies conducted outside of laboratory settings have become increasingly important to HCI research (c.f. McMillan *et al.*, 2010; Sharp *et al.*, 2007; Rogers, 2011). Rogers (2011) posits that laboratory studies can fail to capture the subtle complexities of the systems, contexts, and social situations in which the technologies and applications are ultimately to be placed. Most commonly it is the difficulties in deploying a complex system in a real-world setting and having it succeed which are missed in laboratory studies, especially when it comes to understanding how people apprehend, use and appropriate technologies in their own terms and for their own immediate purposes.

The tabletop research community has mainly focused on technical challenges such as: multi-user and multi-touch input (e.g. Dietz and Leigh, 2001; Epps *et al.*, 2006; Hancock *et al.*, 2007; Tse *et al.*, 2007); extending display technologies (e.g. Kakehi *et al.*, 2006; Hilliges *et al.*, 2009); recognizing and tracking objects (e.g. Ebert *et al.*, 2013; Olwal and Wilson, 2008); and addressing interface challenges including orientation (e.g. Hancock *et al.*, 2006; Shen *et al.*, 2006), and reach (e.g. Nacenta *et al.*, 2007; Toney & Thomas, 2006).

A significant difference between controlled and in-the-wild studies is that in the former, groups of participants are brought to the tabletop and shown their place by a researcher or assistant and provided with instructions on what they have to do: there is someone at hand to explain the purpose and functionality of the

application. These demand characteristics are largely absent in the wild, making for a very different user experience (Rogers, 2011). Research is needed to discover what happens in practice and how we can design applications for group working.

To date, most evaluation work on multi-touch techniques and systems has been lab-based, aimed at answering specific questions about group use and has typically employed comparative quantitative methods (Wallace and Scott, 2010). Although field trials of interactive surfaces are now beginning to emerge, we still know little about how people come to understand how to use these potentially unfamiliar technologies, particularly in walk-up-and-use scenarios where a coherent group of people will use the tabletop. Understanding the context of different potential uses for this technology is crucial.

3.2 The Importance of Context

In order to design tabletop applications for real-world purposes, it is necessary to consider the context of their use. It is important to consider the appropriateness of the technology, the application, the design approaches, and the implications for the wider system (Wallace and Scott, 2008). To say context is important seems redundant at first, but in reviewing the literature it has become apparent that context plays a larger or greater role in the success of a technological intervention. When designing prototypes for lab-based research the contextual environment is very stable and predictable. For public settings the environment is much more unpredictable and variable. Some forms of technology are more immune to contextual factors, perhaps because skilled and practiced operators use them in a very tightly controlled individual manner.

Tabletops however, are commonly aimed at casual use by variable numbers of people. The wider factors surrounding this design arena have the possibility of contributing to a greater extent to the success of a particular solution.

Tabletops are highly sensitive to context and should therefore be created to be as robust as possible: they should be understandable by a wide range of users, be easy to recover from errors, be easy to understand where the users are in the process etc. This can extend as far as computationally restricting the interface in order to reduce the set of possible operations (Piper *et al.*, 2006).

One of the features of the approach undertaken in this course of study is to widen the focus from just studying the interaction paradigms to including content design, sensitivity to context and supporting both individual and social collaborative use. Hence the use of the term 'system' to describe a tabletop in context. This marries with the idea of 'systems thinking' which is a term describing the approach of design where an entire end to end interaction flow is considered in relation to the context of its use and its surrounding spaces and events.

The experiential factor of using these systems is difficult to evaluate. However, this factor is crucial to consider when discussing in-the-wild systems as the degree to which users become immersed, experience affective change and relate the experience with the system to their personal lives is a key component of their engagement and motivation to start using the system, keep using it and return back to it. Their engagement with the content, satisfaction with the interaction and social experience are all part of creating a successful public

tabletop system. These factors are notoriously difficult to evaluate, as they are subjective, momentary and personal.

The fluidity heuristic is an attempt at forming a coherent model for lightweight evaluation of a systems ability to provide a satisfying interaction. Brignull & Roger's notion of the thresholds of awareness and interaction and the honey-pot effect (2003) help to describe the initial steps of motivation towards engaging with these systems. However, a fully coherent framework for evaluating tabletop systems in the wild is yet to be formed.

Understanding the context can be as simple as considering the basic who, what, when, where and why questions (Sharp, *et al.* 2007, Wallace and Scott, 2008). This is discussed and developed in Chapter 9 of this thesis, in the discussion and evaluation of the two in-the-wild studies conducted in this course of research.

Fleck and Haswell (2001) discuss the importance of taking the 'soft' elements of technology into account, such as social and procedural effects. Whereas some applications will require less consideration of external factors, collaborative tabletop applications will require a high degree of sensitivity to the context of their use.

3.2.1 In-the-wild Observations

Ethnographic studies of existing spaces and systems can lead to insights as to where technological interventions can add value. In this course of study, prolonged ethnographic-style observations were carried out in the situated spaces that were being considered as potentially interesting. This ecological form of analysing user needs and understanding existing methods of working,

information gathering, learning and collaboration led to a realistic understanding of the potential impact designing a tabletop solution could have.

A key dimension which defines ethnographic studies is how much interaction the researcher has with the people and objects being studied. Some studies are characterised by a very minimally-intrusive style of observation. For example, Kruger *et al.*, 2004, and their analysis of non-digital tabletops, consisted of observations of groups of people engaging in a collaborative activity. By analysing one aspect in particular—orientation—they were able to categorise three functional ways in which orientation is used in collaboration (in comprehending information, coordinating action and mediating communication). Other papers in this style include Müller-Tomfelde & Schremmer, 2008, and Scott *et al.*, 2004.

Another approach to conducting ethnography-style research is to act as a participant-observer, where the researcher actively participates in the system being studied in the hope of understanding through doing. Both approaches were used in the studies outlined in this course of study. Insights drawn from these studies can be of a more personal and anecdotal nature. Ryall *et al.*, 2006, reported on observations and experiences with tabletop computers and made a series of findings, including the fact that adult users tended to be wary of using the tabletop at the same time as other people, primarily out of concern for accidentally touching other people's hands or arms (a similar observation was made by Morris *et al.*, 2006). They also observed that the mode of interaction was primarily single-touch, even though the tabletops used supported multitouch, and suggested that this might be due to familiarity with mouse and stylus driven systems.

Studies by Peltonen *et al.* (2008) and Jacucci *et al.* (2010) found that members of the public who interacted with a large interactive wall display tended to work in parallel rather than collaboratively. While collaborative work can require loosely-coupled parallel work, the needs of the problem should be considered to see if this is a suitable way of working. Designing for collaboration should be explicit and intentional, and the degree of shared (tightly-coupled) work to parallel (loosely-coupled) work should be taken into account.

There have been some pioneering *in situ* studies of interactive surfaces. Kirk *et al.* (2010) created a system that allowed scanning and archiving of family memorabilia with a touch interface called *Family Archive*. Their study took place in three homes for one month each, and they describe how it disrupted family roles and was most commonly used asynchronously.

Cao *et al.* (2010) developed a narrative construction tool called *TellTable* on a Microsoft Surface. This was installed in a school library for approximately two weeks, where children were able to use it during breaks as well as during some lessons. They found that the tabletop fitted into the existing school culture. Access was controlled through a booking system implemented by the librarian. The tabletop application drove the development of genres of storytelling, practices of planning and an emerging culture of storytelling reputation.

Other researchers have studied interactive surfaces in public settings where users might be expected to encounter the technology only once and for a short period of time, also known as a 'one-shot' setting (Brignull and Rogers, 2003). O'Hara (2010) describes a (single-touch) tabletop system in a café, highlighting issues related to moving between interactive and non-interactive use: for

example, the interactivity could draw attention to otherwise innocuous gestures such as tapping on the surface, causing social discomfort. Hornecker (2008) describes a multi-touch system in a museum that asked users questions about natural history. She found that while it proved engaging, it failed to encourage social interactions and subtle usability issues impacted the experience. Hinrichs *et al.* (2008) describe how the visibility of a (single-touch) museum installation in use drew groups to interact (similar to the 'honey pot' finding of Brignull & Rogers, 2003). Access was managed through turn taking, with some members temporarily leaving the installation while waiting to use it.

Peltonen *et al.* (2008) provide a detailed video analysis of people using a large vertical multi-touch display called *CityWall*. This was installed in an empty shop window in a city street and was designed to enable photo browsing. They highlighted several phenomena: the influence of users in drawing attention to the display, performative actions to communicate intentions or to engage others in playful activity, and patterns of shared use. Shared use involved primarily parallel activity by both strangers and acquaintances, but also working together in a more tightly-coupled fashion. The participants resolved conflicts, where the activity of one user interfered with that of another, spontaneously. The same group of researchers (Jacucci *et al.*, 2010) also describe *Worlds of Information*, another walk-up-and-use vertical multi-touch display for browsing media. This extended the *CityWall* system with novel 3D interface widgets, aiming to encourage parallel interaction and user engagement. This system was studied *in situ* at an exhibition, and indicated that users found the system (although not the content) to be engaging. Multiple people used the system in parallel: singly, in pairs or in groups.

3.2.2 Shared Interfaces at NASA

As Huang *et al.*, (2007), discovered in their study of the NASA MERBoards—a set of 50” interactive screens used for the Mars Rover project—there were unexpected circumstances which led to difficulties in their use in a real-world setting which their designers could not have anticipated in advance. They make reference to Davis (1989) and the connection between perceived ease of use and usefulness and the uptake of new technology. Both these factors are found to be important in the studies conducted in this course of research and are described later in this thesis.



Figure 3.1: NASA engineers and program manager using a MERBoard screen to discuss information.

The design of the MERBoards applications was difficult due to the unique nature of the collaborative tasks it was required to support and changes in mission requirements. The suite of applications run on the MERBoards included: a graphical tree-building planner which allowed for mapping out alternative

plans for rover actions; a general purpose whiteboard; access to a central data repository and individual data directories.

In terms of users' perception of the usefulness of the system, an issue with shared screens is that users must spend time experimenting with the applications to get a feel for how they might work best for them, but not having a sense of ownership they might be self-conscious spending a long amount of time becoming familiar. Users may also be wary of appearing inept in front of other workers because of the visibility of the screen in the shared workspace. The potential usefulness of the system as a tool for supporting collaborative annotation of documents for mid-size meeting was hampered by a lack of time during the deployment for training.

As mentioned by Wallace & Scott (2008) users must perceive a shared resource as easy to use so they feel confident trying to use it without fear of looking foolish in front of others. This is in contrast to a personal-use system, where mistakes are less likely to have negative social consequences.

The issue of how people take ownership of a shared resource is important to consider, as their perception of how available the resource is at any given time and individual differences may affect how the system is appropriated. If a shared resources is integrated into a group's regular workflow then it is more likely to be used than if it is separated. In some situations it might be beneficial to create a system for organising the shared use of a system, but initial observations indicate that it is normally enough to allow normal social processes govern its use, such as turn-taking and discussion. In the case of

MERBoards, there were some cues that a board was in use, even if the person using it had left momentarily, such as identifying a logged in user on the screen.

It was not possible to iterate the design on the MERBoards during the deployment due to NASA invoking a code freeze during the mission. Until such shared resources are more commonplace, and conventions surrounding their use and interaction begin to emerge, it will be necessary to adaptively iterate the design of similar systems to respond to the unique requirements of each environment.

3.2.3 Recommendations for Large Display Groupware

Huang *et al.*, 2006, suggest that large-display groupware systems are more likely to be used regularly if they are integrated into existing workgroup interactions. Although this seems obvious on the face of it, integrating a new mode of interaction into a workflow can be challenging and the system must clearly demonstrate a tangible benefit if it is to be taken up by a sufficient number of users. They also note that users spend less time on average exploring the features of large display groupware than groupware designed for desktop displays. Rather than attempting to support general collaborative processes such as sharing documents, they recommend making the supported tasks more specific. By supporting a specific task and extending what is possible over using a laptop or desktop system, the application is more likely to be used regularly. Simply transferring applications from the desktop to a larger screen and assuming that the increased screen real estate will drive greater motivation is a mistaken assumption.

Having a specific task in mind when designing the system may help to scaffold users motivation and if sufficient flexibility is afforded, users may appropriate the system for other tasks.

The researchers note that the visibility of a user's interactions with a large display serve not only as an instruction for their purposes but also to advertise that function to observers

The existing studies mentioned above hold relevant insights for the research themes of this thesis, but differ in various ways. Peltonen *et al.* and Jacucci *et al.* found that designing for explicitly collaborative interaction can be achieved, even with members of the public, but that content quality can be a major factor.

CityWall and *WorldsofInformation* were based around a vertical touchscreen whereas in this thesis we are exploring the issues of tabletop form factors.

Systems such as O'Hara's Café-based system were single-touch, and did not have a strong collaborative problem-solving task at their core. Other researchers have focused on multi-display environments with the purpose of supporting collaborative work including BlueBoard (Russel & Gossweiler, 2001) and Tivoli (Pedersen *et al.*, 1993), which work as whiteboard style tools, similarly to MERBoard. Digital tools which attempt to emulate the affordances of pen and paper (or whiteboard) tools often have difficulty reaching the same degree of usability and flexibility.

Sometimes, having a less featureful set of interactions and content can promote more engagement (Allen, 2004). Users are able to naturally explore a wide range of gestures for interaction, and are certainly more confident and skilful in 2013 than they were when this course of research began, when the iPhone and

iPad were not ubiquitous. Certain on-screen elements invite different types of gesture (e.g. photos and maps naturally invite translation and pinch zooming) and have reasonably well understood affordances. Design conflicts in interface design can occur. For example, lack of borders (chrome) on elements makes them hard to handle: The drive to reduce visual clutter can leave some affordances less visible and reduce the native learnability of the interface.

'Immediate Apprehendibility' is an important factor, since if the system appears boring, confusing or effortful users will be drawn towards more interesting exhibits (Allen, 2004). The first attempts at interaction should, as far as possible, ensure to be successful and promote the users' feeling of competence and promote further exploration of the value of continued interaction (Gammon, 1999).

Curiosity about tabletop systems drives initial interaction but the novelty of tabletops is ever-reducing and can only hold the users' interest for so long. Most interactions are quite short and casual. Engagement is typically shallow and few users naturally form collaborative units. The majority of discussion revolves around how to use the system. This indicates weakness in the designs as, ideally, the system is easy to apprehend in terms of purpose, content and interaction.

Tabletop adoption in most real-world studies is voluntary. Most systems in in-the-wild studies are not explained in context with regard to purpose and interaction method. This contrasts with lab-based studies where the users have been primed on the tabletops purpose and instructed how to use it. Encouraging users and ensuring that they understand the value and purpose of the system is

important. Tabletops are also typically deployed in environments where there are many other objects and displays competing for the visitor's attention. The quality and value of the system must be obvious.

Deploying a tabletop system in the wild also means one can predict less about the demographics of the user set. Age, educational background, attitudes towards and experience with technology, dexterity and propensity towards self-guided learning and exploration are all factors about which the designer cannot make assumptions. However, successfully abstracting a complex layer of technology away from the user can enable casual and playful interaction.

Keeping the balance between playful and deeper, structured interaction is difficult. If the user only sees the potential of the tabletop as having one level, that of playful but meaningless interaction, they will not be motivated to spend time exploring further. Having a low barrier to entry but effectively communicating the depth and breadth of content, interaction styles and learning opportunities is a challenge.

Reliable touch registration is also a challenge and a robust input-sensing platform leads to more satisfactory experiences and less confusion stemming from uncertainty in whether an intended touch is registered or not, accidental touch events or failed registration of intended touch events. This can be ameliorated through input technology choice, choosing appropriate surface materials, calibrating carefully and providing visual or auditory feedback.

The above points are a sample of the insights garnered from the review of literature on in-the-wild touchscreen and collaborative systems. These are used as recommendations in the designs of the prototypes employed in this course of

research as well as evaluative frameworks. Although there are some clear factors which apply somewhat generally to tabletops, such as ergonomic principles, and the fact that text entry on a touchscreen can prove difficult, other factors are more difficult to express as clear guidelines, such as emotional factors, motivation, and 'the X-factor' which can make a system successful. These elements are best explored iteratively and reflectively in the development of tabletop systems.

3.3 Studies in Museums and Exhibitions

Some notable studies of co-located technology use have come from analyses in museums and galleries of visitors' interactions with exhibits and with each other. Social interaction has been shown to make a critical contribution to people's experience of an exhibition. People discover the functionality of interactive art installations through interactions with people nearby (both those known to the visitors and strangers) and negotiate access with others in the vicinity. The public visibility of exhibits also allows visitors to create engagement and participation through performative activity; drawing others into interaction and keeping them engaged when they start to drift away. Despite this, many interactive systems limit co-participation with exhibits through inflexibility in the single user interactive model typically adopted and interfaces designed only to be used by one person at a time. Even museum systems designed for use by multiple people can encourage multiple single user interactions. For example, the multi-touch system described by Hornecker (2008) asked users questions about evolution and different species, but didn't encourage any kind of interactions between them. It was also beset by usability

issues. These led to shallow conversations about how to use the interface rather than about the content it was designed to engender engagement with.

While the overall picture from museum studies therefore is of poor support for group interactions, there are successful cases. In a recent paper, for example, Hornecker (2010) describes an application designed to be viewed through a periscope device in a natural history museum. A version of the application redesigned to support easy disabled access with simple tangible controls and a large screen positioned at an angle on the floor serendipitously proved to be more successful for groups of visitors, as it encouraged rich social interactions around the system.

Brignull & Rogers (2003) noted how physical aspects of the environment could influence the likelihood of people engaging with a large display at an event in a public space. They suggest for example, placing a display in a location with a constant flow of people. They also discuss how other people can create social affordances within a space: the so-called 'honey pot' effect. Rodden *et al.* (2003) carried out an analysis of interactions in a travel agency, highlighting that the monitor placed between sales staff and customers created a barrier to successful interaction.

3.3.1 The Tree of Life

Hornecker (2008) describes an in-the-wild study of a tabletop in the Berlin Museum of Natural History. The application, called 'The Tree of Life,' mainly revolved around a question-answer text about animal species and was created by a media design company in Germany in 2007. The tabletop was located in a hall dedicated to evolution. The application allowed users to browse

information accessed through question prompts (such as “are marsupials born inside the pouch?”) and when touched an answer appears with text and images.

Hornecker describes the tabletop as being large enough to allow four users to interact without interference. An icon of a hand was shown next to each ‘question bubble’ in order to prompt the users to touch them. The tabletop itself is based on a capacitive sensing technology, which was quite inaccurate.

Attempts to mitigate this through the design of the interactive elements’ behaviour were a mixed success. For example, the close button required a long-hold touch and expanded during the hold to give feedback. However, because this was the only interface element to do this some users were confused. All the interface elements were quite large. Touching the surface on a non-bubble area generated an expanding tree-like visualisation.

The various levels of interaction afforded different styles of interaction, from the playful to the serious, with the tree shoots animations keeping children amused while the adults read the text. This is a good idea as it supports holding the attention of parents and children in the same space and affords an opportunity for parents to explain things to their children.



Figure 3.2: The Tree of Life tabletop in the Berlin Museum of Natural History

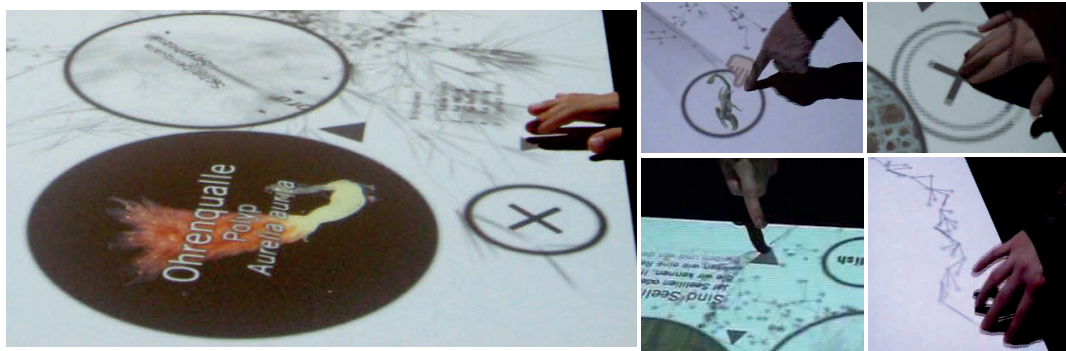


Figure 3.3: Some interface elements

Hornecker employed a ‘rapid ethnography’ style of research over seven days, which started with open-ended observations and led to iterative analysis of emergent issues. She found that users did not hesitate to try out rich gestures, including multi-fingered and bimanual, or hesitate to interact whilst others were using the tabletop (as observed by Ryall *et al.*, 2006). Users were observed using variations of gestures, such as touching buttons with different numbers of fingers. Users would also stroke the surface and walk their fingers to create interesting visualisations (see the above figures). There were very few

'throwing' gestures, as the interface did not support this, only allowing tap-presses and scrolling of text.

Certain inconsistencies in the interface behaviours were observed to cause confusion. For example, some of the bubbles were interactive whereas others were not. The appearance, and therefore the learned affordance, was identical, leading users to try and interact in ways they had succeeded in before. This confusion could have been avoided by providing a visual cue to the different behaviours. As mentioned before, the close button required a long press, which was different to other elements, but it had a similar circular style to other elements that responded immediately. This was intended to reduce the accidental removal of elements but would have benefitted from a different visual style to communicate the different interaction requirements.

Another source of interface confusion was the operation of the arrows for scrolling the text in the bubbles that contained text. Although it was possible to scroll the text by swiping up or down directly over the text, arrows were placed on the left which moved the text up or down at a fixed rate. However, the direction of text movement for the arrows was unclear and some users were observed attempting to use the wrong arrow which, for example, would scroll the text up when it was already at the top. In one case, a pair of users were observed spending 1:40 trying to understand the interaction model – a very long amount of time in comparison with most casual users' efforts. Several users are observed tapping quickly at the buttons and becoming confused because these taps are not registered due to the latency of the system. This leads to confusion about their attempts at consistent interaction.

The probable source of the confusion with the arrows which control the scrolling is that they operate in the opposite direction to the metaphor of the direct scrolling method. That is to say, the direct scrolling method behaves as if the text was on a sheet of paper and moved with the swipe. However, the buttons operate like a traditional desktop scrollbar where the scrolling is achieved as if a window is moving over a fixed sheet of text. The researcher postulates that having these interaction methods adjacent but which operate in opposite direction leads to a “perceptually conflicting mapping” in the user’s mental model of the interaction mechanism. The lack of a frame or visible boundary to the text region also led to confusion as the systems response to a similar input would change depending on whether or not it was in the area of touch input for the text.

The capacitive sensing technology which underlies the touch input could be triggered by users accidentally. This could be either from leaning against the edge of the tabletop or placing a hand or finger within a few centimetres of the table surface. This is due to the fact that, as a capacitive technology it can detect electric fields without physical contact. This led to some accidentally registered touch events which caused confusion for some users. A common example is the attempt to refer to an object on screen by pointing (without touching) and a touch event being registered without the user’s intention. Since deictic referencing in conversation is common this is a problem with the system design. As has been mentioned, it is important that the users feel that they understand how the system operates and that it reacts in a consistent fashion or there is a risk that they will feel that they are doing something wrong or that the tabletop is broken.

3.3.1.1 Analysis

Over a 70-minute period of observation, more than 50% of visitors interacted with the tabletop. Of these users, 36% were children who engaged in a playful manner with the 'shoot' animations, and 64% actively read the question and answer 'bubbles'. Of those who read the bubbles, half left after reading one item. The remainder, who engaged for longer periods of time, represented approximately 17% of the total number of visitors to the space. Another 25% of the whole number of visitors observed others interacting and read information displayed on the tabletop. Hornecker notes that this is a positive result and higher than the average for a museum exhibit.

The 'honey pot effect' was also observed, meaning that when the tabletop was in use, some visitors would observe the tabletop and the users and then were more likely to start interacting with the tabletop themselves. This leads to a 'chain' of continual use, with observers replacing users as they leave. In this study chains of serial use of up to 10 minutes were observed. This was possibly helped in part by the fact that the tabletop was large enough to allow for multiple simultaneous users so that observers did not have to wait to start interacting. Hornecker also notes that when the room was less busy, chains of non-use would occur as visitors attention would not be grabbed by the inactive tabletop and not cross the 'threshold of interaction,' or ignoring it completely and therefore not crossing the 'threshold of awareness'. The researcher notes that the periods of non-use may be exacerbated by visitors not realising that the tabletop was interactive and interactivity was commonly discovered by accident, such as when leaning over to better see some text. Children were more likely to discover the interactivity in a shorter period of time due to a

comparative lack of hesitation in touching objects (and being reprimanded by parents, being told “don’t touch”).

The themes of social interactions visitors had with each other around the tabletop concerned issues of how to interact with the tabletop and less about the subject matter of the content. Other studies of museum exhibits have shown that family groups tend to discuss the information they are reading, with parents posing questions to children (Sanford *et al.*, 2007). In contrast, conversations at the tabletop were less likely to be of an educational nature. Unlike certain other multi-user multi-touch applications such as CityWall (Peltonen *et al.*, 2008) and ToneTable (Taxén *et al.*, 2004), the Tree of Life tabletop did not engender collaboration among different users. This is most likely due to the nature of the application being more passive and having less focus on creating collections or new objects.

The researcher notes that most comments she received about the system from visitors were mostly critical. The tabletop application was described as being “for children” and not offering much serious educational value. Hornecker makes a recommendation of extending the content in the application to include deeper layers of content to invite users to spend more time interacting and engaging with the application. She says:

“An alternative design approach for museum tabletops might aim at supporting calm and reflective interaction or to present phenomena and activities that initiate sense-making, construction and testing of hypotheses, discovery and meaning making, or dialogue and emotional learning.”

3.3.2 Vancouver Aquarium

Hinrichs & Carpendale (2010) performed a study of two tabletop systems in the Vancouver Aquarium. The first, called 'Collection Viewer,' evoked visitors' curiosity through visual interest and open-ended exploration. The second, 'Arctic Choices,' went into a greater depth of detail concerning environmental issues and was found to trigger discussion among its users. The researchers discuss which factors served to attract the visitors' attention, what the users did at the tabletops and the nature of the social and collaborative information exploration. In addition they make several points about usability issues relating to in-the-wild tabletop systems.



Figure 3.4: The two tabletops *in situ* at the Vancouver Aquarium.

The study was concerned with the following questions:

- What attracts visitors to walk-up-and-use tabletops?
- How do visitors approach the tabletops?
- How do visitors experience the tabletops and make sense of the information presented?
- How do visitors experience the multi-touch aspect?

- What characterizes information exploration on tabletops?
- What role does social and collaborative interaction play?

Hinrichs & Carpendale conducted an ethnographic study of the two tabletops over eight days and captured video from several angles. As well as taking notes from a distance they also engaged in 'shadowing' whereby they followed four groups as they went around the aquarium. This allowed them to gather additional insights about how visitors experienced the other attractions, interactive exhibits and kiosks etc. and compare this to their experiences at the tabletops.

3.3.2.1 Analysis

To analyse the video data, Hinrichs & Carpendale employed a 'two-pass' strategy. The first transcription pass was performed quickly and the interactions times and activities were logged. This provided data on the duration of interactions, instances of repeated interaction, and an overview of the general activities undertaken as well as specific moments of interest marked for further detailed analysis.

3.3.2.2 Findings

A general observation of the two tabletops was that they evoked curiosity, perhaps as these types of device are still a novelty, with several people posing for photos with the tables. The fact that, from a distance, visitors seeing the tables for the first time would be likely to see other people interacting with a horizontal surface, but not be able to see what they were doing, would pique

their interest. The phenomenon of interest being generated in the tables by other peoples' use is described as the 'honey pot effect' by Brignull & Rogers (2003), and has been noted several times in previous studies of interactive technology in public spaces.

3.3.2.3 *Adults vs. Children*

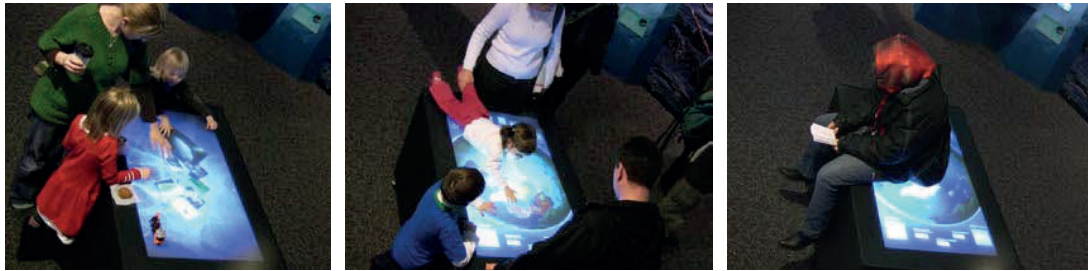
Both adults and children expressed interest in the tabletops but differed in their initial behaviours. Children tended to use the tabletop immediately and explore in a free-form fashion, whereas adults tended to watch either their children or other users with interest before deciding to interact themselves. This is akin to Brignull's observed 'threshold of interaction,' whereby people's comfort with using the system is important and their decision to try and interact with the table depends on them feeling confident enough to know how to use it successfully and get value from their interaction beforehand.

The tables were also observed to interact well with the surrounding exhibits, with visitors gesturing from the tabletop to other rooms and then moving in that direction. Visitors would also move between the wall exhibits and the tabletops indicating that the tabletops were valued as being a complementary source of information to the more traditional murals.

3.3.2.4 *Reappropriation of Tabletop Hardware*

Hinrichs & Carpendale also observed something seen in other in-the-wild tabletop studies, which is that many people still see the interactive tabletops as tables and use them in the ways were are familiar with using traditional tables. For some visitors, the cues to using the tabletop as a place to rest objects such as

cups, food and babies outweighed the fact that they were obstructing the interactive screen. As long as the tabletops are designed to withstand these uses, it is generally a positive tendency and designers must take advantage of the different ways of interacting with the tabletops and support users' other needs which are currently tied to use of horizontal surfaces.



(a) Food items and toys on the Col- (b) Child lying on the Arctic Choices ta- (c) Woman sitting on the Arctic
lection Viewer table. ble and reaching for the lens tool. Choices table.

Figure 3.5: Examples of re-appropriation of a tabletop.

3.3.2.5 Multitouch Gestures

The two tabletop systems supported the standard multitouch gestures for pictorial assets, i.e. rotate, translate and scale in addition to buttons required in order to operate interactive assets such as video media. An important aspect of multitouch systems is that the on-screen objects behave as the user would expect, which is to say with simulated physical properties. These govern the objects' behaviour with relation to having simulated mass, inertia, friction and having material properties such as elasticity. This makes interacting with the objects on screen close to interacting with physical objects and this has been found to be an appealing feature of multitouch devices. It also provides a number of functionally assistive side-effects such as being able to 'throw' and item across the tabletop by releasing a touch when the object is at speed, and

giving indications as to certain limits of range, such as bouncing back off the edge of the screen or flicking through a scrolling list.

This behaviour allows designers to show that the system has registered a touch but provide visual feedback that the interaction is constrained.

3.3.2.6 Exploring information

There are several approaches for exploring information and describing the underlying motivation for doing so.

Known Item: When the user knows exactly what they want and that it exists.

The interaction consists of a target pattern directed at locating the item using known properties through search or browsing.

Increasing Acquaintance: The user wishes to gain a sense of what information is represented in the collection.

Exploratory: The user wishes to find something which matches certain features, but does not have exact requirements. This process involves browsing, or following an “information scent” and the user may dive into several subjects depending on their interest in the moment.

Serendipitous: The user is exploring the information set without a definite subject in mind and may be doing so out of curiosity or to keep themselves busy.

Selective Research: This is an approach to increasing knowledge and gaining insight from the set of information present in a semi-exploratory fashion. It is focused on finding multiple items that have a degree of perceived importance.

Comprehensive Research: This is an approach to exhaustively finding every item on a particular subject.

3.3.2.6.1 Visual Curiosity and Information Exploration

Responses from the interviews and observations of how users explored the information suggest that a majority of the interactions were driven by curiosity and the visual appeal of the objects. For example, objects which stood out visually because they looked attractive or featured an animal were more likely to be interacted with. Also, the more interactive elements such as the videos were popular, with one interview respondent mentioning the richness of the media and the sense of a story.

One respondent mentioned the low resolution of the tabletop, an issue with the current generation of tabletops such as the Microsoft Surface in general, in particular reference to objects such as maps, where small text labels were hard to read. This resulted in the map objects being less popular. In general, text is less successful than visual media such as photos and video in tabletop applications. As well as being difficult from the viewpoint of resolution, readability and orientation, reading text is a process that feels at odds to the more playful open-ended interactions concerning photos for example.

While open-ended exploration was favoured by several interview respondents, other expressed a desire for a more structured exploration. This suggests that designing applications to support several methods of exploration is beneficial as it is not possible to predict which type of exploration a random user will prefer. For example, the authors suggest the addition of colour coding the media objects in the Collection Viewer so users can explore by theme instead of purely randomly. Another means of exploring connected information would be to add a

button which allowed the viewing of related content as guided by the users choices.

3.3.2.6.2 Playful Interaction

The aquarium visitors may have one or several of these exploration modes in mind at different times when interacting with the tabletops and can change between them rapidly and seamlessly. Of course, users may also interact with the tabletops in a ludic fashion which is not related to information but motivated by play and primarily driven by visual and motive stimulation. This can be singular or in competition or cooperation with other users. It was interesting to note that in several cases this form of playful interaction served as an entry point to longer periods of interaction where the users engaged with the information. The authors note that several users initially touched the surface with one finger, primarily the index finger, and observed the response of the table. From this tentative interaction users typically then tried more elaborate interactions.

In general, children exhibit more overt playful interaction, often throwing objects around the screen quite vigorously. Adults were observed also playing with items, albeit with more restrained physical expression. This affordance provided through free-form touch interaction can provide a platform for adults and children to interact, and the commotion can attract attention from other visitors towards the table. At a guess, the difference between children's and adults' interaction reflects their expectations of what this object, the tabletop, is for in the absence of other information. For children they see the direct touch and physical properties of the objects and overlay their mental model of playful

interaction on top, whereas adults see the information and have a mental model of museum furniture being a conduit for learning.

3.3.2.6.3 First Steps, Curiosity and Sensation

If the user has not observed other people interacting with the table, the authors postulate that this initial touch is part of the users process of understanding the interaction method and gaining confidence. They suggest that users may have initial questions such as “is this exhibit interactive?” “If so, how can I control the items?” and “how does it feel to do so with direct touch?” The last is an interesting question – the question of the affective experiential quality. Many first-time users of direct-touch systems report that they enjoy the experience and find it exciting. This makes it a self-motivating interaction and the expectation of it being a fun experience motivated the users to make the first interaction and cross the “threshold of interaction.” Although users may be able to satisfy the first two questions by observing other users the last question cannot be resolved without that user actually touching and it is this curiosity, perhaps, which drives the ‘honey pot effect.’

3.3.2.6.4 Reflection

Another important mode of interaction is reflective review. Visitors to the aquarium could use the tabletops at the end of their visit, having previously seen the other attractions. In Hinrichs & Carpendale’s interviews several of the participants mentioned the value in looking at objects and forming connections with things they had seen in their visit. Being visually reminded of already known information can trigger connections and support reflection on their

experience, cementing knowledge and forging deeper insight or simpler help visitors remember things they had forgotten.

3.3.2.6.5 Collaboration

As found by Dillenbourg (2008), although tabletops are heralded as being a useful tool for collaborative work (Scott *et al.*, 2003), most groups tend to form parallel exploration modes with minimal content sharing as a matter of course. Rather than exploring items together, visitors would browse the items separately and share certain other items with other visitors.

The authors note that the highest incidence of collaborative exploration occurred among parents and children. This typically consisted of the parents remaining passive and observing the children's exploration, or the children showing items to their parents. Parents were also observed scaffolding their children in either an intellectual way by suggesting which items to explore, or a physical way by actually controlling their hands to help them interact with the interface.

Observed instances of collaboration would typically involve the communal viewing of a video item. A group of visitors would collect around a corner or edge of the tabletop and one user would enlarge the video to make it easier for the group to view. Other group member might make adjustments to the orientation so the video was facing the centre of the group, and one group member might hold the video with a finger while another operated the controls.

3.3.2.6.6 Awareness of Others

One aspect of co-located work at tabletops is that one user has a certain degree of peripheral awareness of the other users. This level of awareness is presumed to be greater than other forms of simultaneous work on other devices such as exploring information on separate laptops. The ability for users to channel their attention fluidly between their own and other's work allows for more serendipitous discovery. The high degree of other-awareness also allows for efficient parallel work streams. This is presumed to be a positive effect as several interview respondents mentioned it favourable and mentioned that they became aware of media items which they would otherwise have missed. Field studies of touch-enabled wall displays (such as Peltonen *et al.*, 2008; Jacucci *et al.*, 2010; Brignull & Rogers, 2003) have also shown user's awareness of neighbouring actions, but as the authors note, with a tabletop the circle of neighbouring interactions can encompass more users.

Hinrichs & Carpendale also observed visitors assisting each other and engaging in lightweight interaction with visitors from different groups. A typical example is of one visitor who is familiar with the tabletop system and the controls assisting a new user through either verbally or physically scaffolding their learning. Typically children used physical methods, such as pressing buttons for them, whereas adults were more verbal. Other-directed awareness can also reduce the number of 'collisions' and interference with objects which other users are interacting with.

Although a larger tabletop might reduce the number of 'collisions' and interference, it would also reduce the level of mutual awareness. Therefore,

considering how large to make tabletops is an important concern and should reflect this understanding of the trade-off between individual space and awareness.

3.3.2.6.7 Interaction times

The researchers found an average interaction time of 2.17 minutes in total: 2.39 minutes on average for children, and 1.94 minutes for adults. So-called 'empty' periods where nobody was interacting lasted for 1.18 minutes on average. 1/5 of children and 1/7 of adults interacted with tabletop more than once. Some visitors came back as many as six times. This is quite an encouraging set of results as this is in line with how long people typically interact with non-digital exhibits.

3.3.2.6.8 Learnability of Interfaces and Systems

Several of the interviewed visitors noted that interaction with the tabletop was intuitive and easy to use. The authors note: "visitors often tried to interact with media items as they would interact with paper on a physical table." The limits on the interaction were typically expressed in confusion with the system misrepresenting the users intended touch. This is a common problem with vision based tabletop systems, as the pad of the finger has to be applied with sufficient pressure to be visible to the camera system and register as a touch event. Often users adopt ineffective finger technique meaning their intended action is not registered by the tabletop. Unfortunately, there is no easy way of providing feedback when this happens. However, the instances where a user makes a touch which is registered by the system but does not affect the interface for a particular design reason can be shown to have been registered,

such as with the touch ripples and tether visualisations employed in the Microsoft Surface SDK SP1.

In addition, when multiple users were interacting with the system simultaneously (the authors observed up to 10 people using the tabletop at one time), the touch recognition could get confused and result in apparently random effects. This problem would probably be reduced if the users spent a longer time interacting together. Typically, a new user focuses their attention tightly on the area around their fingertips and is less aware of what other users are doing. If the same users continued for a period of time it is possible that they would identify when these 'random' effects were actually caused by interference of touch by each other. The severity of these effects can also be affected by the design decision of who 'owns' an object when touching it. Should the first touch registered on an object remain as the primary anchor point, or should new touches supersede it? The design of the Collection Viewer application in the aquarium meant that users could 'steal' other users' objects by touching and dragging even if the first user was still 'holding' the item. This resulted in frustration, which could have been averted if new touches had a lower priority.

The result of these problems related to fine-grain control of the objects on screen meant that several users abandoned efforts to master this and, for example, reoriented themselves around the tabletop rather than using a rotate gesture to orient the media object to their perspective. The position of onscreen controls is also worth noting. Given the low degree of accuracy that features in most novice tabletop users' interactions, interface elements should be separated sufficiently to avoid accidental errors. For example, in video items in the Collection Viewer, the 'more information' button was adjoining the 'delete'

button, which resulted in several users accidentally deleting a video they were interested in seeing more information about. Simple interface layout decisions like putting irreversible destruction buttons away from other types of button reduce overall frustration.

3.3.2.7 *Summary of Vancouver Aquarium Study*

Hinrichs & Carpendale report that the two tabletops deployed in the Vancouver Aquarium positively impacted the visitors' experience of the Arctic Exhibit. Among other reasons for the success was the fact that the content matched well with the surrounding exhibits and so enhanced the visitors' experience in context with their related experience of the exhibit. It did this by allowing individual, parallel and social exploration of information, leading to new discoveries, deepened insight and connection with the other exhibits and serendipitous discovery.

They note that several visitors expressed a wish for access to more in-depth information as well as the ability to direct their exploration according to themes and related content. The interface produced some frustration with accidental button presses and difficulty controlling the media objects through quirky design and small buttons being the main offenders, as well as the common issues of interference when many people are using the tabletop simultaneously. Shortcomings in the interface often lead to users wither abandoning entirely, or not attempting to engage with the content in favour of playful interaction.

In this case it may be preferable to use a larger size tabletop in order to support separate groups to simultaneously interact without disturbing each other.

3.3.3 Arctic Choices Table

The Arctic Choices table application used the same device platform as the Collection Viewer. The application provided an interactive map, which allowed the visitors to explore certain aspects of the Arctic, with a focus on ecological threats. Visitors were able to view animal migration paths, yearly cycles in ice formation and projected reduction in Arctic ice coverage.

Visitors' statements revealed that they had a high level of interest in this tabletop, due to the "really important" subject matter. Being able to support a data driven exploration of the topic was valuable to the visitors.

Observations made by Hinrichs & Carpendale suggest that, due to the data-heavy nature of this application and the need to integrate knowledge whilst using the application meant that a certain minimum age (which they suggest to be 8 years) is required to interact in a "meaningful" way. The represented information is less visually rich than the Collection Viewer and significantly more abstract.

Visitors reported enjoying seeing information that was relevant to their lives, which they had heard reported in the news, in a visual way on the map.

Visitors spent longer observing other users before interacting compared to the Collection Viewer. This higher 'threshold of interaction' might be due to the more complex nature of the information represented and the more structured interaction style. Typically, users focused on the map area first, as the largest element and possibly the most familiar. The researchers suggest that this serves as a familiar entry point and most visitors appeared to try and understand what information the map is representing. From there the visitors' attention fanned

out to adjoining controls. These interface controls were visually similar to those on the iPhone, which helped make the interface feel familiar and intuitive, with several visitors mentioning that they had used similar controls before.

3.3.3.1 *Interaction Times*

Contrasting to the Collection Viewer, adults spent longer than children on average interacting with the Arctic Choices application (1.75 minutes for adults and 1.2 minutes for children). Adult visitor groups interacted for up to 20 minutes. The average 'empty' time was 1.8 minutes between interactions.

3.3.3.2 *Interface Design*

As befits the subject matter, most participants perceived the interface of the Arctic Choices applications as more complicated. Presenting complicated content on tabletops is typically challenging since manipulating the information usually requires multiple controls and these cannot be minimised in the way WIMP interfaces allow. This is offset somewhat by the richness of the multi-touch gesture set which allows manipulations not possible directly in WIMP interfaces. Care must be taken in designing for tabletop systems to reduce complexity as much as possible, eliminate modal interaction if possible and reduce visual clutter (Guimbretière, 2002).

As the authors note, the design of the Arctic Choices interface is not optimal for novice users. Given the different style of interaction compared to the open-ended exploration of the Collection Viewer, it would be possible to provide an interface which scaled in complexity as the user gained experience and therefore appear less intimidating in the first instance. Given the short amount

of time that a public-facing application has to compete for the attention of potential users, communicating what the application is for and how to use it is a priority. The risk, otherwise, is that people will not expend enough time and effort in trying to understand what they can get out of the system and how to use it and therefore abandon it.

3.3.3.3 Collaboration

The researchers found that users of the Arctic Choices system to be more likely to interact collaboratively than with the Collection Viewer. They postulate that this could be due to the complexity of the interface and hence the propensity to assist each other or fall back on external assistance. Users were observed actively discussing the effect each parameter had on the map visualisation with other group members and to collaboratively decide what further selections to make. Hinrichs & Carpendale note that, although the interface did not lend itself to interaction from more than one person at a time, this had the positive effect of inciting more discussion which was focused on the content of the Arctic Choices system, and the interactions were more focused with intent compared to the Collection Viewer which prompted more playful but less deep involvement with the content.

Interestingly, one person from the group would tend to be in charge of controlling the interface while the others members of the group would watch and discuss as well as make suggestions to the 'controller'. This is similar to what was observed by Rogers & Lindley (2004), where groups using an interactive whiteboard tended to form the same group structure with one 'scribe' and several contributors. This could possible be due to one person

having the easiest physical access, self-selecting himself or herself as a dominant group member, and then the extra effort of displacing them is deemed not worthwhile for the other group members (I don't mean that they resent the scribe, I mean not worthwhile purely in terms of effort and social coordination). Another reason for this is simply that it is an effective strategy for one person to familiarise themselves with the controls, while others are able to keep a high-level view of the information represented in the interface and strategize about how to explore the information. Whereas the controls in the Collection Viewer table were distributed – anyone could access from any edge of the table and start interacting with the images without having to grasp the meaning of the information represented – in the Arctic Choices table the controls are aligned to one orientation (repeated on opposite edges) and require some insight to use effectively.

This potentially points to a way of enforcing collaboration, as the result was that visitors collaborated more and focused more attention towards understanding the information presented. That is to say, by making a small but noticeable barrier to interaction and a fixed position to reach the controls, one person in the group will emerge as the 'controller' and the others will become observers and contributors and engage in a collaborative fashion led by discussion.

Visitors who did not know each other would also use the system simultaneously. As before with the Collection Viewer this led to a few problems. Some of the interview respondents mentioned that they got confused when other people were interacting with the tabletop and making changes that made it hard to follow what was being represented on-screen. Other people

mentioned that they felt inhibited with respect to making changes which would disturb the other people using the tabletop. This cross talk meant that it is probable that some visitors did not spend as long with the tabletop as they would have if it were less busy.

3.3.3.4 Summary of Arctic Choices Study

Visitors were motivated to use the Arctic Choices table and were interested in the content. There were some issues with the design of the interface such as the division between control space and information space and interference from unrelated groups of users trying to use the interface simultaneously. This made it harder than necessary to track the cause and effect of using the controls and the changes in the map overlays. The researchers also found that the visual information on the maps contained too much clutter and were hard to read. This led to many visitors abandoning the tabletop, as the barriers to entry appeared too high.

3.4 CityWall

In 2008, Peltonen *et al.* published their findings from 8 days of observations of CityWall, a 2.5 m wide multi-touch screen made using a shop window in the centre Helsinki, Finland. Although this screen was vertical there were several observations of multi-user collaboration which make it interesting for this thesis. The system displayed a real-time feed of photos tagged 'Helsinki' from Flickr. Approximately 15% of people observed to be in the groups did not interact directly with the screen but did watch others using it. Of the 1199 people who interacted, 18% were individuals, the rest were part of groups of two or more people. The size of groups was predominantly 2, with 72% of

groups being pairs. This does provide support for the social nature of large screens.

The researchers observed two general types of group engagement: parallel work and teamwork. Parallel work refers to people using an area of the screen for interacting and they are not affected by the other activities at the screen. Teamwork refers to groups of users focusing on the same objects at the same time. It could also refer to situations where users are interacting with the objects on the screen and observers are commenting or providing instructions. The nature of the teamwork might be collecting related pictures together, or working in synchronised motion, or making *ad hoc* games resembling *Pong* or hockey.

3.4.1.1 Interference between Users

Several occasions of interference were observed, where the actions of one user or group interfered with the intentions of other users. This was observed as accidental or intentional, and occasionally accidental obstruction led to humorous interactions. At other times, this lead to frustration when people's work areas were obscured by photos that were enlarged to the point where they covered their personal work area. People signalled their reactions and coordinated recoveries through verbal exchanges or through bodily posturing, such as stepping back from the screen or turning towards the interfering user.

3.4.1.2 Social Roles

Teacher-apprentice configurations were the most common social configurations, with the more technologically confident users assuming an

active role and explaining the features of the interface and how to use it to the 'student'. Another observed role was that of 'comedian' where someone would look for objects at the screen to entertain their audience. The authors make reference to Jacucci's (2004) *Interaction as Performance*, noting that people made use of the screen as a 'stage' and the on-screen objects and 'props'. The users also made 'grandiose gestures' which were exaggerated movements meant to communicate certain intentions. The tendency for people, in a public environment, to take on roles to simplify the complex social setting and this mediates the ambiguity between strangers. An interesting consequence of the screen being so large was that there were occasions of multiple different 'classes' of activities taking place concurrently, with different roles played by actors to the audience. The multi-touch nature of the interface allowed for naturalistic interaction that supported expression and signalled intention, facilitating coordination and the acting of different roles.

3.5 Summary of In-the-Wild Studies

The studies described in this chapter represent the thin edge of research on multi-user touch systems. Tabletop research in particular suffers currently from a dearth of studies exploring how to support collaborative tasks with multi-touch, multi-user systems. This led to the focus of this course of research to explore the potential of this form of technology to support more than museum exhibits. As noted in Balestrini *et al.* (2014), there are few examples of HCI studies that demonstrate sustained success in real world settings.

Contemplation of the issues found in the literature review conducted and described in this chapter, and the previous chapter led to the discussion of

existing frameworks and the formation of the nascent frameworks described in Chapter 4. These frameworks attempt to tackle the key issues of designing collaborative tabletop systems and were influential in the creation and evaluation of the prototype systems described in the two studies in this thesis.

4 Frameworks for Multi-User Technologies

In the consideration of the literature review and findings above, and in order to aid the thinking for design and evaluation of the forthcoming prototypes, several frameworks were developed. Given the focus on in the wild contexts, the importance of considering the social factors affecting technology is reflected in these frameworks. A discussion of the social drivers of technology is outlined in the next section, leading on to Fleck & Howells' (2001) Technology Complex, which describes multiple factors that can affect a technology system's success.

After that, I discuss the importance of supporting goals in groupware design, as opposed to individual usability. Following this, a brief discussion on how this is aligned with the fluidity heuristic, especially regarding interaction 'inside' and 'outside' the interface. This leads to the Lean Observe-Build approach, which is a core methodological contribution of this thesis.

The Lean Observe-Build approach describes the philosophy employed in the practical components of this course of research. This includes initial observations and ethnography, choosing a suitable problem area for a tabletop technological intervention, employing 'lean' philosophies to drive quick, iterative development, testing with real users along the way, and the importance of getting the prototype situated in its real-world context as quickly as possible in order to test, refine, and continue to develop the application and other surrounding paraphernalia.

4.1 Social Drivers of Complex Technology

As a human society, we have a desire to make ever more sophisticated tools to increase our understanding, personal effectiveness and interconnectedness. New technologies bring new possibilities and we seem to step closer to a natural co-existence with digital technologies every day. However, simply because we can create new systems from discoveries based in materials science and technology does not mean we are necessarily ready to *design* them.

Understanding technology, human society, and the relationship between artefacts, social structures and culture, is a deep process. We have powerful frameworks for understanding these (such as Activity Theory, Cynefin, Distributed Cognition) but no ‘magic bullet’ in terms of how to repeatedly design successful technological interventions.

One strategy espoused by Norman (2005), is to align with activities. That is to say, take the goal of the user (or users) to heart as the driving force. Heidegger’s model of self-world interaction is one where people interact with objects for a given purpose, in order to accomplish certain goals. I bring these concepts to mind in order to act a lens for understanding the technology and its impact in this course of research. A central theme of the approaches undertaken in the previous chapters is moving from theory-driven exploration of this new artefact, the tabletop computer, to an exploration focused on praxis, real-world engagement, and participant-observer reflective design practices.

I have suggested that theoretical understanding of the fundamental application of tabletop technologies to existing social structures will only lead to limited results. The world of social interaction, collaboration, and in-the-wild contexts

are more of a Complex type than a Complicated type, in the Cynefin model sense, and thus must be explored in a lean and reflective fashion, rather than a top-down, theory driven fashion. As Dreyfus (1991) says, reflecting on Heidegger's conceptualization of tools in social use contexts: knowing that a hammer has properties which come from the fact that it is made of metal and wood is not as meaningful as knowing how to hammer. This echoes Paul Dourish's sentiment: "Embodied interaction is the creation, manipulation and sharing of meaning through engaged interaction with artefacts" (2001). If we hope to understand how to make a positive impact on collaboration through technology, we need to see interactions in real space and time, and in practical social contexts.

4.1.1 Intuition and Coping

Creating an intuitive interface is a challenge. This is not least because there is no such thing as a purely intuitive interface. Every object exists in relation only to other objects, and every experience lies in relation to previous experiences. An interface may be intuitive to someone who has used similar interfaces before. That is, there is an effect of learned behaviour. If a user has over-learned a similar but distinct interface, that can become a hindrance, as automatized, inflexible behaviours collide with the demands of the new system.

When designing for a population of non-specialized users, achieving a degree of interface fit where the majority of users from the public can achieve a useful outcome is a huge achievement. Appealing to the 'naïve user's' will to learn, play, and experiment will lead the way to active learning through interaction. Support the activities which are congruent with the user's context and they will

learn how to satisfice the system. Support multiple pathways through the interaction flow – if a user wants to double-click on a tabletop, let them do it without punishment. It will be impossible to design a single interface to support a complex activity and match all users' expectations all the time. To reduce harmful effect of this, keep communicating from the interface to the user, keep the activities robust and their purpose clear.

Adapt to the user where you can, and trust that they will adapt to the system if you can't. Some users will be able to cope with the system's flaws; others won't and will abandon its use. We can at the very least help them understand that the system does what they believe it does and help them avoid wasting their time trying to cope when it simply does not support their intended goals of desired activities. If the users understand its meaning and the extents of its intended purpose they can creatively misuse it when it suits their purpose. Coping in this sense is not a dirty word – it is also mastery. And people have an instinctive motivation towards mastery.

The core problem which this course of research attempts to address is the issue of how to understand the issues of designing successful tabletop systems for real-world problem cases. The next section, The Technology Complex, attempts to enumerate several factors that can affect technology systems and their success. Given our intended use case of public, messy, real-world contexts, there will be a greater emphasis on the social, cultural, organizational, and location-specific aspects of this framework.

4.2 The Technology Complex

The Technology Complex is an attempt to resolve the various concepts of 'technology' into context-related sub-definitions (Fleck & Howells, 2001). These elements of technology lie along a spectrum from technical to social, as below:

BASIC PURPOSE OR FUNCTION
MATERIAL
ENERGY SOURCE
ARTEFACTS / HARDWARE
LAYOUT
PROCEDURES (PROGRAMS, SOFTWARE)
KNOWLEDGE / SKILLS / QUALIFIED PEOPLE
WORK ORGANISATION
MANAGEMENT TECHNIQUES
ORGANISATIONAL STRUCTURE
COST / CAPITAL
INDUSTRY STRUCTURE (SUPPLIERS, USERS, PROMOTERS)
LOCATION
SOCIAL RELATIONS
CULTURE

Several of these elements are reminiscent of Activity Theory, especially artefacts, social structure and culture. For the purposes of understanding technology in contexts such as in this course of research, several of these elements can be minimised, or assumed as fixed. For example, material, energy source, cost, and management apply more to other types of industrial technology than domestic computing. For the purposes of this thesis we are more interested in the elements of the Technology Complex that form a design perspective. That is to say, certain factors we will assume as being fixed and we are interested in those factors we can say we have influence over.

The hardware is partly fixed, as in we pre-selected tabletops as the main physical artefact. We did alter it in CamPlan by raising it and adding steps for ergonomic reasons, and to change how its affordances were communicated. The software (procedures), layout, and location were under our control to define (independent variables). We were hoping to affect the work organisation (collaborative interaction, data manipulation, planning), and our choices were informed by awareness of social relations and culture, and our desire to support and improve a basic function (health-focused learning or group planning).

Given that the Technology Complex is intended to encompass a wider range of technologies than employed in this course of research, we can attempt to reduce the complexity for our given purpose. The core message of the Technology Complex is that technology is a mixture of physical artefacts as well as social components. Between the design of the physical object and the processes of working with it lie the designable factors of how to communicate to the user how to use it. Certain factors we have no control over, such as the users' level of prior experience, or cultural expectations. Some factors we do have control over, such as how we communicate the affordances of the system, how we choose to situate the device in relation to the other objects in the room, how we tap into ergonomics and human intuitions.

Ultimately, we have the most control over the appearance and behaviour of the software. Therefore, in conjunction with signage as a way of telling potential users what the tabletop can offer them, we must take the advantage of their attention to choose elements of our design which communicate the process and social-related expectations of how to get the maximum benefit from using the system.

“An invention is essentially a complex of most diverse elements – a design for a physical object, a process of working with it, the needed elements of science...its purpose and use in conjunction with other sides of civilisation and its popular evaluation. A change in any one of the elements of the complex will alter, stimulate, depress, or quite inhibit the whole.”

– Gilfillan (1935)

In Gilfillan’s definition of an ‘invention’ above, he pulls the procedural aspect apart from the physical object associated with a ‘technology.’ His focus on the purpose in relation to other sides of civilisation and popular evaluation relate to the importance of perception and context. Context is especially important in this course of work, as mentioned before, due to the social and collaborative nature of the tasks we are trying to support.



Figure 4.1: The categories of the Technology Complex, showing how social, structural, and procedural factors influence the more visible physical layer of the technology.

In Figure 4.1 above, the dimensions of the Technology Complex are grouped into four categories. These categories are arranged to indicate how deeper,

cultural factors influence structural components, which in turn influence the procedures of a given system, which support the physical artefacts and their operation. In lab-based studies, it is hard, if not impossible to accurately recreate the deeper levels, and, as Fleck & Howells state, there is an overemphasis on the physical artefact. This suggests why it might be difficult to take systems from the lab into the real world, or to duplicate the same effects in both contexts.

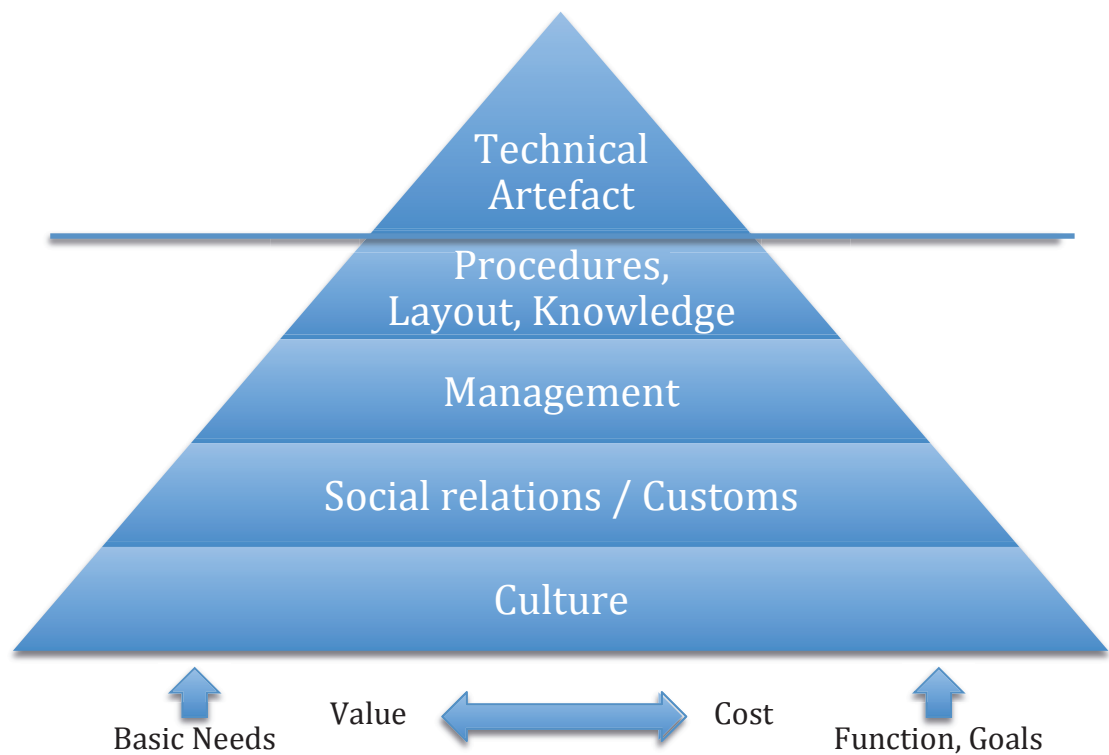


Figure 4.2: Visualizing the categories of the Technology Complex as an iceberg, with the visible tip being the technical artefact.

In Figure 4.2, the categories of the Technology Complex are re-visualised as an iceberg, with the physical artefact being the only part of the deeper set of variables that affect a given technology. The basic needs of the system, how it adds value in a given cultural and organisational context, and how it supports

the personal goals of the people using it, are represented as drivers that give motion to the iceberg, and hence represent use of the system. Without these the iceberg is motionless or sinks.

Given our focus of in-the-wild contexts in this course of research, the Technology Complex helps by serving as a lens, or a checklist, with which to consider the wider context of each tabletop intervention, and to highlight the importance of not just designing the outermost layer, but to be sensitive and reactive to the organisational, social, and cultural factors, as well as existing organisational processes, different levels of experience, and specific location. The next section discusses how to choose the right level to design at, given a certain context and set of aims.

4.3 Designing for Activities

The goals of the people using a certain system are not always in concert with the intended purpose that the designer of that system had in mind. When considering how to design for groups of users, about whom we can say little ahead of time, and who may have differing, or even conflicting, goals, it can be difficult to know how to support them most effectively. Don Norman has called into question the utility of designing for individual users (2005), and proposes designing for activities instead. This level of abstraction allows the designer to have a fixed point of reference in mind whilst the matching of users to activity can be handled by other processes, such as signage, tutorials, etc. The clear communication of what activity the given system is intended to support is therefore crucial, allowing potential users to decide individually, or as a group

whether it is worthwhile engaging with the system for their need in the moment, or at least how they might get value or entertainment from it.

4.3.1 User-Activity Design

In Don Norman's definition of activity-centred design (2005), activities are actions performed by a user to achieve a goal. Norman's framework, however is mostly addressing the needs of a single-user application, e.g. a website intended for use on a PC. If we extend that slightly to include actions performed by another person, either with the application or other users, we can begin to apply the framework to multi-user systems. The activities of different users might differ, but still contribute towards to the same goal. For example, one person might be sorting mixed photos into groups by colour and another arranging these subgroups by photo subject.

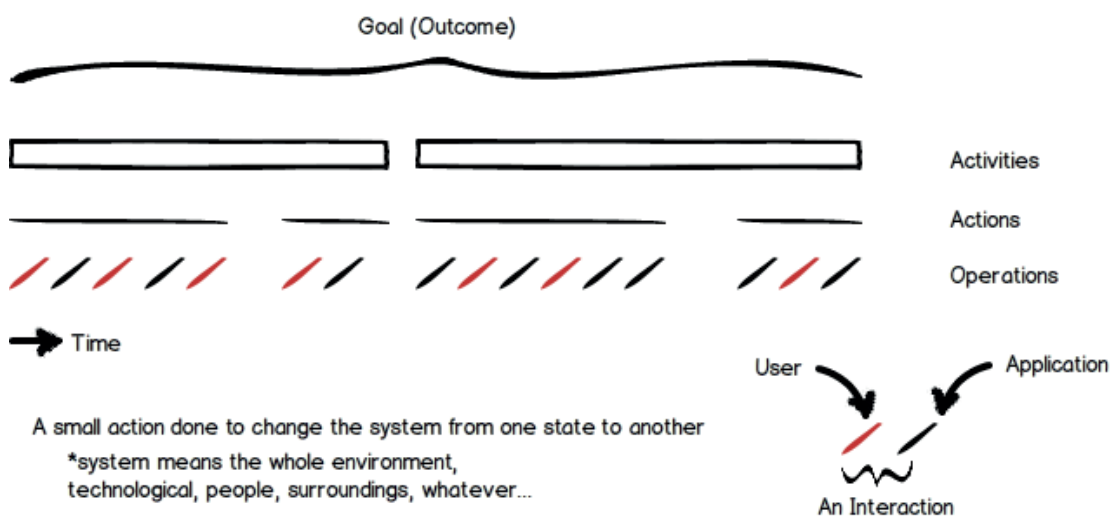


Figure 4.3: A diagram representing how activities are composed of smaller actions and support larger goals.

Norman also talks about activity centred design where the actions are those made by the user. However, given the less linear fashion in which tabletop can be used by groups, it can serve us to think of the application/technology also

performing actions. In some way, the application is just a recording of what the designer thought the appropriate reaction should be in a given scenario, so the application may prompt for some information which is needed in order to complete the goal, or present some information back to the user in response to the user's action of tapping a button.

The actions themselves are comprised of interactions between the user and the application. These then occur in both directions, between user and application, application and user, and user to user. The interactions are a series of low-level operations performed by the user and the application. For example, the application presents an OK/Cancel dialog box, and the user presses OK. The meaning of that interaction is to change the state of the system. According to the programmed logic of the application, the user had to be asked for their input at this point. To do this, the user's attention has to be drawn to the situation, a graphical prompt is generated which the user can process, make a decision and then provide input. That input is then used to change the state of the application somehow (e.g. some logic is performed, a script is run, some data is written to a database). If the logic of the user and the application are in agreement this will move the user closer to their goal, or satisfy the requirements of the system.

Conceptualizing activities in this way, which serve goals and are comprised of interactions, conserves more of the context around action/reaction, cause/effect and the intention of the system. It makes clear the distinction and meaning of the different terms describing different levels of the system process and shows how they add up to help move the system (which includes the status of the application, the understanding of the user, the environment, and other

actors) into a new state which moves the user closer to their goal. In activity theory this would be termed 'outcome'.

4.3.2 In Support of Goals

In a multi-user system, as well as being difficult to characterize the 'user' in this case, as we are dealing with a group of people, the goal is just as difficult to define as there may be different, even conflicting goals held by the group members.

As we will come to discuss in later chapters, we came to understand the goal of the users of our CamPlan prototype as gathering information and planning a trip for a group of visitors to a city. However, it is impossible to say exactly what any one person who enters a tourist information centre is planning of achieving. This is compounded further because many visitors are from other nations, and have different expectations, customs, and experience with particular forms of technology.

It was felt that it was important to ensure that the system had very clear communication about its intended purpose and the activities it supported. That way, even if users' goals conflicted they would be able to discuss their differences and navigate towards a compromise. That is to say, do not make any assumptions about the goal in designing the application; the goal can be defined and agreed upon by the group of users. Simply allow certain activities to be completed in a robust fashion.

In traditional user-centred design we suggest the user is an actor in a system with a singular and unchanging goal in mind; for example, a user visits an airline website to purchase a ticket. We cannot design with this approach in a scenario

where there are a group of users, comprised of mixed experience, goals, and levels of attention, since the concepts of user and goal are too changeable to be of value. For this reason, it was felt important to get the prototype application into its intended context to see how the wider system adapts (including the physical environment, tourist centre staff, members of the public etc.) and refine *in situ*.

This approach is acknowledging the fact that success in a given context can mean different things to different groups and even that different groups can change the context of the space (e.g. when a large bus load of school children walk in and the centre becomes a busy place with dual purposes of providing information to the group leaders and distraction for the students). Users will misappropriate the technology, they will not spend time learning how the system is 'supposed to be used,' and they will only persist for as long as it captures their attention in relation to other factors in the immediate environment. By developing and refining the application *in situ* we are allowing for changes in the design and rapid validation of assumptions. This will be discussed in the following chapters.

4.3.3 The 'Users' of Multi-user Systems

In designing for multi-user systems, the choice of terminology surrounding the human subjects should be considered. In HCI literature, the term 'user' is used liberally. The frame of reference of that term should be reconsidered for the multi-user scenario, however. The term 'user' in many IT-related tasks can be somewhat passive and the term is also loaded with many types of association from years of HCI literature. This can affect the perception of the 'actors' in the

system and reduce them to objectified representations. However, in the situation where multiple people are interacting with technology they are also actively managing their relationships to the technology and with the other people, both through the technology and beside it. They are users of the system, but also at various times observers, directors, detractors – and many others of the roles that appear in social contexts.

Reeves *et al.* (2005) consider the challenge of fully describing the roles and interactions between users and spectators in public technologies. They consider the ways in which a user's manipulations of an interface and the connection in the mind of the observer with resulting effects. The connection between the operative actions of the user at the interface and what a spectator externally observes can be revealed or hidden. They continue by proposing four design strategies (secretive, expressive, magical, and suspenseful) to formally build from their taxonomy of these connections between user input and spectator perception. They continue by discussing how the design of the spectator experience can be critical in supporting learning through observing other users. If the connection between manipulations and effects is obscured, it is harder for observers to understand how to use the system, and therefore less likely that they will become users themselves.

Although the term 'user' is somewhat problematic for this context, other terms such as 'actor' or 'participant' have other issues. I shall continue to use the term 'user' to refer to the people who use the systems described in this thesis, but it is worth bearing in mind the subtle difference in meaning and to be mindful of the perceptual loading of that term.

The roles that the users take in a multi-user system are also less likely to be permanent and to shift quickly. In a public setting, for example, they may take the role whereby they are demonstrating that they know how to use the system. People are also wary of using unfamiliar technology in public for fear of appearing foolish to others. They may therefore take slightly more defensive or dismissive roles, or go the other way and encourage others to interact with the system as validation of their efforts. These social effects co-mingle with the designed-for roles in the system and are another way in which designing for multi-user systems is more complex and can be affected by unpredictable interactions.

Imagine a situation where the 'user' of the system does not interact with the technology at all, but by the social nature of tabletops is able instead to conduct their goals by interacting with another participant who performs the interactions with the technology. Since we are designing for multiple users, these types of interaction and others are more likely to occur.

Rather than focus on users as agents conducting a transaction with a system we should consider their *lived experience* of the technology – what they bring from their lives before they encounter the technology and what they do afterwards. What causes them to pay attention, and what triggers them to decide to interact? How do they come to understand the purpose of the application and the means of controlling it? Why are they in the space we are interested in and what are they seeking? What motivates them and what opportunity is there to provide an experience that is helpful, but also surprising and delightful?

Although considering these types of questions can be valuable when designing a tabletop system, we have to be mindful of the constraints present in our technology. There is a limited ‘canvas’ for interacting with the users—primarily the screen. However, group activities can consist of more than just interaction ‘inside’ the interface, and the nature of the interactions occurring between the group members must be taken into account.

4.4 Mediating Group Interactions through Interface Design

If we accept that there are more ‘soft’ elements important in designing technologies where context is important, such as group dynamics, cultural aspects, previous knowledge etc., what are we able to do to help guide the novice user to a successful interaction? Are we able to control for factors such as variability in group members’ willingness and ability to “play well” with each other? Are we able to support and scaffold their interactions, providing a shape and structure which can maximise the optimal outcome of these group interactions, with regard to the intended activity of the application?

Reeves *et al.* (2005) describe their framework for designing the spectator experience. This framework provides a structure for the designer of public technologies to shape the way in which an observer of a system in use can understand the intended purpose, and means of interacting with the technology. In designing for multi-user systems, this course of study involved various configurations of user and observer. As noted in the discussion of CamPlan in chapter 8, the progression from observer to user is mediated by the ways in which they are able to make sense of the system, gain confidence in understanding how to use it, and using other environmental cues such as

signage and its context, before making the transition. This is similar to the Honey Pot effect described by Brignull & Rogers (2003), whereby use of a public technology is helped by having a chain of users who can be observed by the person waiting to use it next, lowering the threshold of interaction.

As well as the external cues which encourage users to first be made aware of a system, and then to decide to try and use it, once at the interface there are only a limited number of things we can do in the case of a collaborative technology intervention such as a tabletop (for example, because it's horizontal display is only visible to people stood close to it). We can design the interface to suggest ways in which it should be used directly (it's 'internal' affordances) such as providing buttons whose appearance indicates that they should be 'pressed' (i.e. communicating the affordance of the on-screen elements). We can also provide information on a higher level regarding how the interaction should be performed, such as via posters, which provide cues as to the purpose of the system as well as its intended method of use.

What is less well understood is how to indicate how the application is designed to support collaboration 'outside' the interface, i.e. between members of the interacting group. Certain cues on tabletops such as directionality of text and interactive component, and proximity to certain edges, can suggest how the designer intended people to position themselves around the device. We explore this in the two prototypes described in the following chapters.

Are we able to imagine activities where we can design a tabletop application that is robust and simple enough to support a group whose members have different expectations, and perhaps differing levels of enthusiasm for the group

activity and, accidentally or purposefully, disrupt the flow? Can we provide clear feedback and allow users to understand what has happened and why, even if they weren't looking at the screen at the moment someone made a disruptive action?

Alternatively, are we able to appeal to people's better instincts, and let those who come to understand the interaction more quickly help their associates? Can we assist those who are shyer to make a contribution in a group, perhaps through less obvious actions and without having to step into a leadership position in the group?

Designing the interaction both inside and outside the interface can be achieved through visual cues, interactive policies, allowing users to move backwards in the application flow, giving clear direction as to the purpose of the application and the requirements of the users at various stages. It is also possible to make effective use of personal and public territories, allowing for individual and shared activities seamlessly. We can provide checkpoints, mitigating the potential for 'free riders' to make lesser contributions, and to allow for group reflection and the consideration of the activity from different levels. We can encourage collaboration and awareness by requiring certain actions to be performed by two or more participants simultaneously.

Designing for multiple users requires considering not only the human-computer interaction, but also the computer-mediated human-human interaction. The designer of a groupware system must use all available assets at their disposal (such as signage, location, orientation etc.) to guide the group in their external arrangement, behaviours, and collaboration. Designing for this, as with the

interface itself, can be approached in a lean *in situ* fashion, as discussed in the next section.

4.5 Lean Observe-Build

Rapid iteration in order to react to the subtle social and contextual factors is important when introducing a technology intervention.

"An essential aspect of a painter's canvas and a musical instrument is the immediacy with which the artist gets something there to react to. A canvas or sketchbook serves as an "external imagination", where an artist can grow an idea from birth to maturity by continuously reacting to what's in front of him."

– Bret Victor, 2012

In the past few years a concept called 'Lean' has entered into software development and product management practices. Going hand-in-hand with Agile practices, Lean espouses doing the work of validating concepts before building them in full fidelity. For example, an idea for a new feature for a word processor could be a button that when pressed colours alternate paragraphs red and blue. A simple concept such as that could be tested with representative users by simply asking what they thought in order to understand if and why such a feature would be useful. On discovering that the feature would not be used by almost any users, two months of design and coding are avoided.

Unfortunately, too many software projects are led by 'good ideas' that are developed without validation. This is understandable since validation requires many skills that are not accentuated in an average software team. It also introduces uncertainty to the plan and requires that several 'ideas' be

developed in tandem to allow for the fact that some might not be deemed valuable.

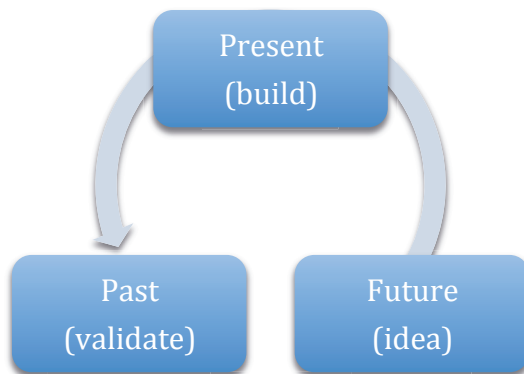


Figure 4.4: A cycle reflecting a 'waterfall' development process. Generally speaking, proponents of the lean methodologies criticise 'waterfall' approaches for moving from ideas to execution in full fidelity without first validating the basic concepts.

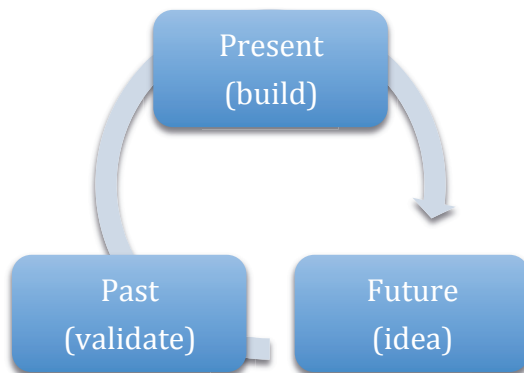


Figure 4.5: A cycle reflecting a 'lean' development process. One of the most important shifts in thinking in lean approaches is to reverse this circle of thought and action. This figure shows how ideas are quickly evaluated and validated in low fidelity forms first, before the concepts are realised in more concrete forms (the build phase).

Concepts such as 'Lean,' as discussed by proponents such as Ries (2011), can lead to more efficient software product development by validating concepts with real users at a lower grade of fidelity before committing to fully build in code. For example, an interface concept can be tested with users in a 'paper prototype' without having to be built fully in an interactive form. In the figures above, three different thinking styles are presented as temporal concepts. Designers tend to think in 'future' styles: imagining 'what can be.' The 'present'

style reflects day-to-day activity: continuity, planning, and preserving order.

The 'past' style encompasses all that is verifiable, grounded in data, and certain.

Figure 4.4 illustrates how, in an unvalidated approach, a design idea might be built, and then pushed out into the world only to discover that it doesn't work.

This is tempting for programmers to do, since the act of validating the utility of a feature is something that happens automatically once released: the presence of the feature or product in the marketplace means that it will be chosen or not by the public. Figure 4.5 illustrates moving through these concept phases in the opposite direction, and front-loading the validation process before building in full fidelity. This may seem like extra work as another representation of the concept must be produced, such as a paper prototype, and then members of the public must be found, observed interacting with the prototype, and then their reaction must be interpreted.

However, developing ideas in smaller increments of fidelity and validating along the way allows for greater understanding of the nuances of the system and emergent properties of the system. As mentioned previously, the emergent properties and unexpected reactions of users to tabletop systems, the dense nature of collaborative work, and the complication arising from the social nature of mixed groups lead to difficulties in realizing successful tabletop applications.

In developing concepts for the CamPlan prototype (Chapters 6–8), we started with rough outlines of ideas, crude sketches and interchangeable patterns that we validated through several stages. Initially we presented the ideas to the tourist office where the study was going to be situated: they were our Subject

Matter Experts. Then we developed the ideas further into paper prototypes so we could evaluate an end-to-end process ourselves (thinking in ways such as considering fluidity), and then with external participants who knew nothing about the project. From there we were able to move forward into building a semi-functional application in code and to test with further groups of people.

Given the sensitivity to context, we were keen to deploy the tabletop in the tourist centre as quickly as possible. This approach is echoed by the words of Bill Buxton: “To adequately take the social and physical context into account in pursuing a design, we must experience some manifestation of it in those contexts (the wild) while still in the design cycle - the earlier the better.” (Bill Buxton, 2007, p.37)

We did so even before the interactive prototype was finished in code, simply using the bundled applications that came with the Surface in order to see how members of the public reacted to the physical presence of a large piece of technology in the room, how they approached it and what they did with it. This led to important clues as to how to improve certain aspects of the CamPlan prototype, such as providing clear signage and instructional content to provide clues to naïve users as to how to interact with the system.

It was key to work closely in a small cross-functional team composed of a developer, a graphic designer, and myself. This approach is a characteristic of successful design projects, as noted by Giles Taylor, Design Director of Rolls-Royce Motor Cars, when asked what was key to the success of Rolls Royce’s automotive designs:

“There was a fusion of engineering: The first companies were generally small, so the actual teams were smaller, and what you’ll find is that the design team worked closely with the engineering team to get proportions—A-pillar to front wheel—and the overall integrity of the proportions and the stance of the car was a more naturally attractive proposition.” – Giles Taylor (2013)³

The approach of working *in situ*, as a cross-functional team, testing ideas rapidly with real users was employed by the Nordstrom Innovation Lab, as described in the YouTube video “Sunglass iPad App Case Study.”⁴ Despite calling themselves an “innovation *lab*,” the group actually worked on the shop floor in a Nordstrom department store, setting up computers, iPads, and video recording equipment in the sunglasses section. The group consisted of designers, UX researchers, and programmers, working together in a time-boxed weeklong session, focused on delivering an app to support the sunglasses shopping experience for Nordstrom customers.

The video demonstrated the success of the approach, showing how unexpected issues, such as the polarization of the sunglasses interfering with the iPad

³ <http://www.forbes.com/sites/hannahelliott/2013/03/28/rolls-royce-design-director-on-why-america-cant-make-cool-cars> retrieved 24 December 2013

⁴ Nordstrom. (2011, September 28th). *Nordstrom Innovation Lab: Sunglass iPad App Case Study* [Video file]. Retrieved from <https://www.youtube.com/watch?v=szr0ezLyQHY>

screen, could be dealt with by reacting quickly with rapid iterative design and development cycles.

4.6 Summary

In this chapter we discussed several frameworks, some existing and some novel, which were applied to this course of research. Firstly the social drivers of technology use were discussed, alongside the need to accept that interface fit for a public technology can only ever be 'good enough' and that users will come to the interface with intuition, and be able to adapt and cope with the challenges of using the interface. Next, the Technology Complex, a formal framework for understanding technology in society in general was discussed and its importance for understanding multi-user public technologies was considered.

This was followed with a discussion on Norman's Activity Centred Design approach, and extended for the particular problems of multi-user public technologies. The concept of what the term 'user' refers to in a multi-user system was then considered. Moving on from that, the ways in which group action can be mediated through sensitive understanding of the wider context in which a technology intervention is situated, and how the ergonomics of an interface can guide the coordination of a group of users was described.

This then led into a discussion of the Lean Observe-Build approach, which is influenced by lean software development approaches, incorporating ethnographic design and co-design. The focus of the approach is in underlining the importance of working on observations, designs, prototypes, and iterative building and evaluating *in-situ*, in order to better understand not only the existing context but also how the technology being introduced changes this.

In the spirit of Action Research, it was decided that the best way to understand a problem is to engage with the target community and to actively participate in building a prototype for a concrete real-world need. Several potential avenues were explored for these prototypes. Some, such as collaborative data mining, were explored only as far as discussions with prominent academics in a related field in order to assess the suitability of the problem area for a tabletop system. Others, such as annotated review of video capture between sporting professionals and their coaches, were explored as far as conducting interviews and ethnography-style observations of the intended user group.

Ultimately, two contexts were chosen for study based on the richness of the problem space and the opportunity to explore contrasting but complementary issues of collaborative tabletop systems. The first was intended to address the problem of patient education during a visit to the Emergency Room of a hospital, described in chapter 5. In this study, a collaborative learning tool was built with the aim of allowing the patient to guide their understanding of their diagnosed condition and corresponding treatment. This designed using a Lean Observe-Build approach in consultation with medical staff, and evaluated briefly in a busy hospital emergency ward. Difficulties with gaining access to a restricted space and adoption of new technology in medical settings are discussed.

The second study was chosen partly to address problems of the first by changing the intended users to members of the public. A different collaborative task was chosen: group planning of a day trip in a new city. The Cambridge Visitor Information Centre was chosen as one of the most popular tourist hubs in the UK, and a lengthy ethnographic-style series of observations and

interviews were conducted to understand the context of intended use. Starting with low-fidelity representations of ideas, the system evolved using the Lean Observe-Build approach, through stages of paper prototyping, user testing, and moving quickly to deploying and refining *in situ*. The system was iterated upon and evaluated over 32 days, and the design and evaluation of the system is described in chapters 6, 7, and 8.

5 Study 1: HealthTable

Facilitating Patient-Doctor Communication

In the previous chapter, frameworks and approaches for building multi-user, public technologies were discussed. Guided by these, this chapter describes the design, deployment and evaluation of a tabletop application in a healthcare setting and how the fluidity framework and flexible design and research methodologies outlined in the previous chapters were employed.

5.1 Introduction

The work described in this chapter was carried out following the initial literature review. Insights and heuristics for exploring a design space of, in particular, multi-user software, had not yet been used in a real-world application. In exploring potential tasks, user groups and contexts I came into contact with M3L (see info box, right). This team possessed a Surface unit and were considering how best to utilise this new form factor and agreed to recruit

Microsoft Medical Media Lab (M3L)

In 2009, I was given the opportunity to work for three months with Microsoft Medical Media Lab (M3L), which is part of Microsoft's Health Services Group based in Washington, D.C, U.S.A. This department is responsible for Microsoft's products related to the healthcare industry. This includes their hospital management system, 'Amalga', a centralised digital system for managing data and processes in modern hospitals. Having received a Surface tabletop unit from the Surface team they were keen to explore the potential benefit and product options of using a tabletop in a healthcare setting.

me for three months to develop and evaluate an application for the health industry.

This was a very intriguing opportunity, as it would mean a completely new tabletop application could be designed and evaluated in a real-world, in-the-wild context. M3L, as a team with close ties to several healthcare facilities, were able to ensure that the evaluation could be carried out in a setting that is normally very hard to gain access to – a busy hospital emergency room. Taking the fluidity framework and considering the specific context of hospital operations and the interaction between doctors and patients, I carried out an ethnographic-style series of observations and conducted several interviews with hospital staff, mainly physicians and management.

However, designing for a hospital context and gaining access to doctors and patients did prove to be a limiting factor, due to time constraints, the slow pace of the approval process and privacy and security concerns. The precise setting chosen – a busy emergency ward – proved to be a challenging place to conduct a study and issues of navigating patients' digital health information and encouraging adoption of new technology by medical professionals were similarly difficult. The short time-period for development meant that the observation, gathering of requirement and the design and development were all highly compressed and necessitated a flexible and agile approach. As the only person working on this project it was also limited by the speed and skill with which I could program the application.

I will describe the initial brainstorming, observations and interviews, development and evaluation of the chosen application and a discussion of its

potential and possible future directions. I also discuss the observations of task, context, and users with regard to how a tabletop intervention might affect these and with respect and sympathy for existing systems and social roles, and to consider the holistic experience in order to provide a successful, collaborative, multi-user tabletop application.

In consultation with the medical professionals who worked at M3L, several potential applications were considered for development. These were: a 'digital dashboard,' a universal data explorer, a consultation workspace and a patient discharge application. These are discussed in the next section and the chosen application – a patient discharge application – is discussed in depth.

5.2 Brainstorming System Ideas

It took several weeks to obtain the necessary permissions to be on the hospital premises to conduct research so I was not able to immediately discuss requirements and possible directions for development with hospital staff directly. However, I was able to discuss some aspects of hospital organization and what kinds of data were available across the hospital network with the developers and medical professionals at M3L.

This 'brainstorming' took place over some informal conversations and discussion of initial sketches, taken from considering all areas of hospital life with a focus on the collaborative scenarios which could benefit from what a tabletop can offer.



Figure 5.1: A doctor and patient convening over a Surface

5.2.1 'Digital Dashboard'

Several potential applications were considered. The first was to develop an application to provide a 'digital dashboard' for physicians and nurses that would allow for greater interactivity with the information displays which are present around the hospital (especially in the emergency ward). These displays provide real-time information about the current status of the ward, including how many patients are admitted or waiting, what their average time of stay is, any emergency messages etc.

In order to extend this it was envisioned that a readout of similar information could be provided on the tabletop but extended with the addition of a list of the currently admitted patients. By selecting a particular patient, more detailed information, including where the patient was located and what stage of treatment they had currently reached could be viewed. The main interaction where this would be useful would be in the handover periods between shifts in the emergency ward. It is very important, when one team's shift ends, to ensure all the important information about the status of the ward and the patients is communicated quickly and effectively to the new team. By adding interactivity

to the display it was thought that this might result in a more direct interaction that would assist in this function. This could be well supported by a tabletop form factor, since the horizontal display would provide additional privacy compared to using a wall-mounted display, and could also be used to gather printed materials in the same place.

Two key problems with this application were that doctors were not always able to meet in a fixed location to carry out the handover and that sometimes the handover was carried out by the head ward nurse rather than the outgoing head doctor. Also, the incoming doctor typically would make handwritten notes and this was thought by one doctor to be easier to do at a PC workstation rather than around the Surface.

5.2.2 'Grand Overview'

Another application considered was a 'grand overview' application which could display all of the relevant information contained in the entire hospital system, giving a ward manager or chief doctor fingertip access to any of the data currently available in the hospital system. The need identified here was that many decisions had to be made rapidly regarding hospital resources in order to flexibly meet the demands being placed on the hospital at any given time.

Accessing information with the existing desktop PC system could be frustrating because many resources are hidden behind several menu options and dialog boxes or even in separate applications entirely. By providing a unified interface for accessing data directly it was imagined that the responsiveness and situational awareness of the hospital management team could be augmented.

The hospital systems contained a very large amount of data, with approximately 80GB of new data being written every hour, and thousands of items of data being written to multiple databases, from x-ray reports to lab results typically being added in the course of treatment of a patient. The challenge with the proposed solution was therefore being able to pull all of this data together and display it in a meaningful way but to also enable the user to quickly 'drill down' to find data in the shortest amount of time and to the granularity they desire. One solution for this type of problem is to display all of the information in a large grid. Given the amount of information being represented, the individual grid elements would not be visible in the overview. In order to actually read the information, one user interface solution would be to allow for continuous zooming, typically performed using pinch gestures. However, another solution was proposed which involved making a fish-eye 'puck' which would allow for plastic deformation of a grid through interaction with an interface element approximately the size a hockey puck.

The advantages of this solution would be that row and column headings could be displayed permanently allowing for a more contextual navigation, either by displaying them at the edges of the screen or at the sides of the 'fish-eye' zoomed grid cell. The other advantage was that by having a plastic deforming data table and a movable fish-eye 'puck' element, it was possible to have more than one area of interest zoomed simultaneously, which could afford direct comparison of data in different parts of the system. This is something doctors frequently have to do, for example, when comparing measurements of blood tests carried out at different times.

However, such an application would most likely be used by a single user at a time, and therefore it does not take advantage of the multi-user capabilities of an interactive tabletop. Also, it was found in using the prototype of the 'grand overview' application that it was unusable for the large amount of data that the hospital operations consisted of. When more than one thousand items of data were included it became hard to view and navigate, owing to the relatively low input and display resolution of the Surface.

Another potential application—the handover app—was rejected on several grounds such as privacy concerns concerning access to confidential patient data and the fact that individual doctors had different styles with regard to how they manage the handover, with some preferring a short verbal catch up to a full walk-about tour of the ward. The possibility of allowing for doctors to design their own layout for this task was considered, relying on a separate application to 'roll-your-own' interface, whereby doctors could lay out specific pieces of live data according to their needs. This was rejected as being too complex.

5.2.3 'Consultation Workspace'

A regular consultation with a doctor and patient consists of being seated with the patient describing their symptoms and the doctor listening, taking notes as necessary and looking up or entering information using a PC.

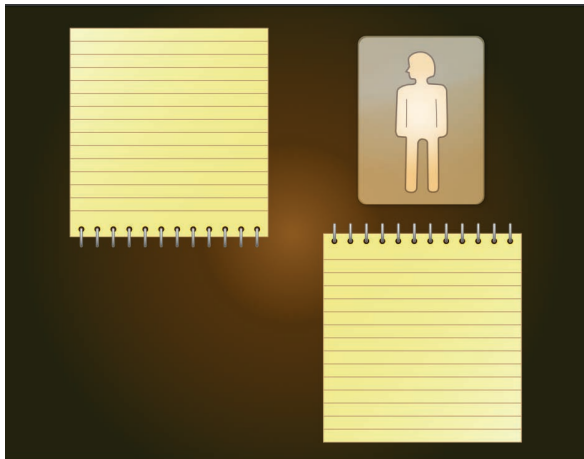


Figure 5.2: A diagram showing a mock up of the consultation workspace.

Generally, physicians like to use visual tools and simple diagrams to support their efforts in communicating with patients. Sometimes they may refer to illustrations, posters or models to act as visual aids to scaffold their words. The consultation workspace was envisioned as a tabletop application which would provide easy access to visual reference materials, medication charts, patient records etc. It would also allow patient to make notes they could take away with them and provided a ‘mannequin,’ which they could annotate to describe the extent of their symptoms or make other points visually.

This application idea was transformed into the concept that was developed further, and is described below.

5.3 Background: the Existing Doctor-Patient Relationship

The ER department of a hospital is a busy place, described by one doctor I spoke to as ‘controlled chaos.’ There are big gains to be had by making small increments in process, although changes are hard to make when doctors have little time and large suspicion of new technologies, and resist the effort required to learn new systems and to adjust their existing processes.

A critical interaction between the doctor and patient occurs at the end of the visit when the doctor is going to discharge the patient from the ward. If the doctor has time, they might go through the patient discharge procedure personally, but commonly this responsibility is handed to a nurse. While being discharged, the patient has their diagnosis explained to them and any expectations of treatment are discussed. If they have been prescribed medication, its use and side effects are described. The patient then has to sign forms, which are later scanned in for digital archiving.

5.3.1 Patient Education

A study into patient-doctor communication by Olson & Windish (2010) revealed that 77% of doctors thought that patients understood the diagnosis they were given but in fact, on testing by another doctor, only 57% were able to recall the important facts about their diagnosis and treatment plan. Only 58% of patients thought that doctors explained things in a comprehensible way. Two-thirds of patients reported receiving a new medication in the hospital, yet 90% noted never being told of any adverse effects of these medications. Nearly all physicians (98%) stated that they at least sometimes discussed their patients' fears and anxieties, compared with 54% of patients who said their physicians never did this

The conclusion of Olson & Windish's paper was that "significant differences exist between patients' and physicians' impressions about patient knowledge and inpatient care received" and that "steps to improve patient-physician communication should be identified and implemented."

Hulka *et al.*, 1976, in a study on patient understanding of medication, stated: “The major problem was communication; a third or more of patients were unaware of the expectation in specific instructional areas.”

In a meta-review of doctor-patient communication outcomes, Stewart (1995) said: “Most of the studies reviewed demonstrated a correlation between effective physician-patient communication and improved patient health outcomes.” Meanwhile, Haskard Zolnierrek & DiMatteo, (2009), in a meta-analysis attempting to estimate the magnitude of the effect, found: “there is a 19% higher risk of non-adherence among patients whose physician communicates poorly than among patients whose physician communicates well.”

Meanwhile, Piper *et al.* (2010) conducted an evaluation of tabletops for supporting health care in older adults. They found support for tabletops as being a good choice of technology, stating that they were “less intimidating, less frustrating, and less overwhelming than a traditional computer.”

In discussion with several doctors at the hospital about the Olson & Windish study (the findings of which were available before the 2010 publication date and were brought to my attention as several of the doctors I worked with had attended a conference in which these findings were discussed), it emerged that some were surprised that there wasn’t even more of a gap than the researchers found and admitted the need for better tools to communicate with patients in the emergency ward where time is a limited resource. The overall need to improve rates of adherence to treatment and to lower return rates is also a financial issue for the hospital as many of the patients attending are without

insurance, so a re-admittance for the same condition costs the hospital dearly in both time and resources.

5.4 Design of HealthTable

Taking the consultation application idea and considering how it might be altered to help with doctor-patient communication in the ER, I engaged in some quick and dirty ethnography, sharing sketches with doctors, and developing their ideas into the design. At this point, I did not have access to patients, but I was able to ask people in the office about their experiences with emergency room visits.

5.5 Eliciting Requirements

Not being satisfied that the other application ideas had significant value, and given that I had, by this point, been granted access to the hospital I made an appointment to meet with the head of emergency medicine at Washington Hospital Center and conduct a tour of the department. He confirmed that the doctor-patient communication issue was the most valuable challenge to address.

5.5.1 Hardware Choices

A Microsoft Surface retail unit was chosen for this system. This was for several reasons. Firstly, M3L had recently been given one by the Surface team in order to explore options for health-related applications. Also, and very importantly, since I was the sole developer available to build the software, the Surface had just had a major release of the Surface Software Development Kit (SDK 2.0).

This meant I had a mature and flexible software development toolkit to start with, which aided in development speed and quality considerably.

The hardware itself is a 108 × 68.6 × 53.3 cm box resembling a coffee table with a 1024 x 768 resolution screen occupying most of the top surface. It uses infrared lamps and IR-sensitive cameras coupled with vision input software to detect touches on the surface based on reflection of the IR from the pads of the users' fingers.

The development environment is based in the C# language and the Windows Presentation Framework, and I used Microsoft Visual Studio to code and debug the application.

5.5.2 Symmetry and Asymmetry

At the time the research was being conducted, the displays in the ER were mounted high on nurses stations, designed to be used as standing workstations. When doctors wanted to show patients media such as x-ray images, they would have to turn the monitor around to face the patient, whilst navigating the interface with a keyboard and mouse. This was quite an awkward interaction and was a good fit for improving with a tabletop application. This is similar to access and visibility issues found in medical technology settings by Cecily Morrison (2008).

The observation of the asymmetry and awkwardness of this form of two-party interaction is similar to that found by Rodden *et al.*, (2003). They found that, in a travel agent setting, the agent had control over the screen and several forms of information. The customer in this case was left feeling as though they had less

influence on the planning of a trip and were less likely to make suggestions, and sometimes felt uncomfortable asking for information.

To prevent this from happening in the case of the HealthTable, we designed the tabletop interface to be easily accessed by both parties, with the hope of creating a more 'symmetric' interaction. This takes into account the differing social status and relative authority in this setting, similarly to the discussion of technology and social systems from the workplace studies of Heath & Luff (2000).

5.5.3 Rapid Design

The design of the tabletop application was quite rapid. The design of interface elements was fairly obvious as it was mainly concerned with viewing images. Most prototyping was done directly in code at the tabletop in order to reduce the development time. Security was a consideration, and printed 'fiducial' cards (2D identification markers) were chosen as a primary authentication method, utilising the table's ability to recognise objects placed on it.

Navigating the interface was quite simple. After authentication the doctor could select which patient they were with, and all the media generated by the patient's visit was presented on the screen. To assist navigation, three viewing modes were available, which were modelled on physical paper metaphors. The first was simply to spread the objects across the screen randomly and allow for manual organisation. The second was to arrange the objects in a grid which eliminated the overlapping and was akin to laying out pieces of paper across a desk uniformly. The last was a 'coverflow' style which allowed serial browsing

of the objects and was similar to leafing through a stack of paper one page at a time.

It was also considered that the tabletop could be integrated into other aspects of the discharge process. One such aspect is giving the patient 'Krames' discharge instructions, which are pre-prepared notes about their diagnosed condition. This information is printed out and given to the patient to take with them. As mentioned, there is also a cumbersome step in the existing workflow where paperwork has to be printed out, collected by the doctor or nurse, signed by the patient and then scanned back in for digital archival. This could be streamlined by signing directly on the screen.

In order to assist with education, a collection of medical images produced by Gray's (a medical illustration company) was considered to be included. The doctor could access this imagery whilst explaining their condition to illustrate anatomical relationships, for example.

5.6 HealthTable System Development

One factor which is very important with tabletop interfaces is responsiveness. Because tabletop users are usually uni-tasking, it can be frustrating if they have to wait for data to load, or confusing if interface elements do not respond immediately to their touch input. With medical imagery, the size of files used is typically very large, and network traffic within the hospital is usually very heavy. For this reason it was decided that a local cache of patient data would be kept on the encrypted local hard disc of the Surface unit itself.

The caching of the local data could be done continuously in the background with a separate background service that would also take a certain amount of load

away from the interface programs and help with parallelisation, as database queries are frequently synchronous and can result in long wait times. Collating all the patient data necessitated making multiple database queries as the medical imagery records and other patient data were distributed across hospital systems.

Every minute, the list of admitted patients was read and matched with patient name and unique ID. When a new patient was admitted and entered into the system, a new folder was created with an xml file containing metadata about the patient and the image and movie assets contained within subfolders. Only new data for each patient was then pulled from the server and rewritten, if necessary, to an appropriate scale and format. By reading the xml file, the interface program was able to very quickly load all the relevant data for a patient and be ready to use within seconds. Pulling data on request from the hospital database would otherwise take up to several minutes, depending on how much imagery is associated with their treatment.

5.7 Consultation with Doctors

When the application was in a state of sufficient development to be shared with the doctors, a meeting was arranged to gather feedback. The below pictures show an early but functional prototype of the application. It was felt necessary to show the application at a stage of development where it was possible to interact with the media, rather than still images, as the doctors evaluating it had not used a similar system before.



Figure 5.3: The first consultation with the head of emergency medicine and two other staff doctors in which the patient discharge application is shown.



Figure 5.4: Showing prepared imagery alongside patients' scans.

The purpose of the meeting was to validate any design choices that had been made so far in producing the application and field suggestions for new features. Development efforts up to this point were deemed as fruitful and the go-ahead was given to continue refinements and plan for a deployment.

5.8 Emergency Room Patient Discharge Application

The following sections describe some key features of the patient discharge application in detail.

5.8.1 Display Elements

The design and layout of the interface was refined over several iterations and consultations with doctors in the Emergency Ward. Initial concepts came through observing existing methods, and attempting to match existing ways of working as closely as possible to reduce barriers to adoption. The fluidity framework was used to analyse the ways in which interface elements could be arranged to allow for flexible exploration of patient imagery and data without the interface itself becoming a hindrance. As noted in Guimbretiere (2002) a wide and shallow information architecture is well suited to touch displays. Existing paper-based metaphors were utilised, as in accordance with Jacob *et al.*'s (2008) principles of reality-based interfaces.

5.8.1.1 Log-in and Security

Security of information and privacy in its use are key requirements when using medical data. Hospitals in the USA require a double-security system. This means that two separate forms of security are required to gain access to medical data or hospital systems. Typically, for a PC console this would be a smart-card

which had to be put in a reader, and a typed password. With the tabletop application, it was imagined that a smart card reader could be used, or a fiducial marker (which can be printed in IR ink to make it harder to copy). This would then be followed with a 4-digit pin to be entered. However, as the data was encrypted on the Surface and the unit was being supervised at all times (and stored in a locked room overnight) for the purposes of the prototype the log in procedure was simplified to using a log in fiducial card as shown in the figures below. (A second factor of authentication such as a PIN entered through an on-screen numerical keypad would have been simple to develop).



Figure 5.5: Doctors could be given a physical security pass the size of a credit card.



Figure 5.6: The security pass contained a fiducial marker which represented a unique numeric ID.

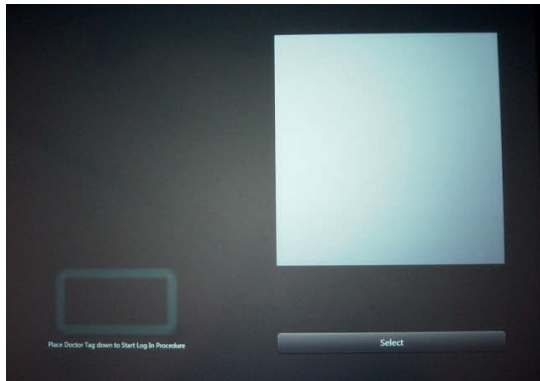


Figure 5.7: The tabletop, when resumed from standby, had a blank appearance with a position to place down the security card.

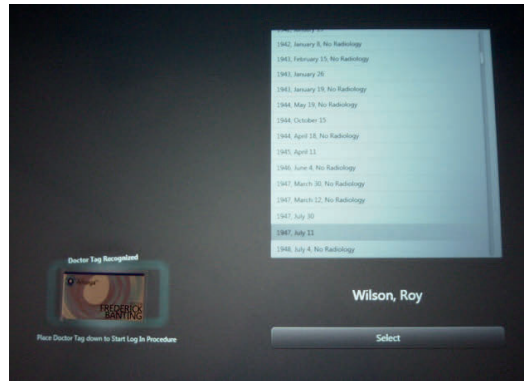


Figure 5.8: The Surface immediately recognized the card when placed on the screen and displayed the patients associated with that doctor. Patients are displayed by date of birth instead of name for privacy. The name is displayed when a date of birth is selected as a confirmation before loading the image viewers.

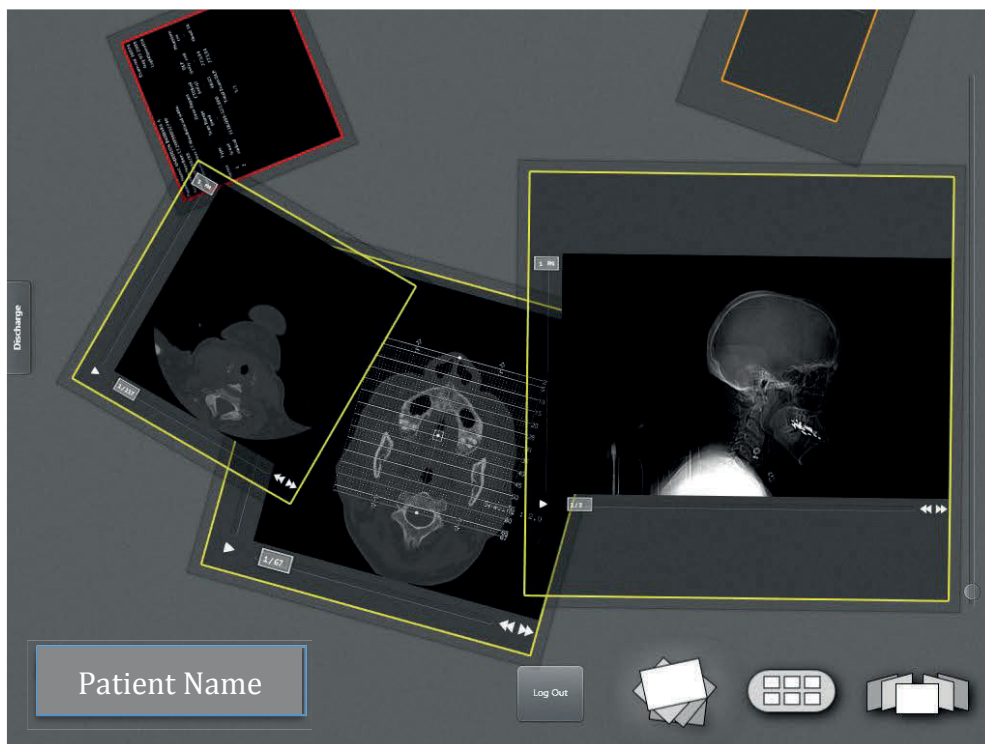


Figure 5.9: The primary screen with the shuffled organization mode and several CT scans

Since the prototype was going to be used with actual patients, for the sake of privacy the names of other patients admitted to the ER were not displayed.

Instead, patients were identified by date of birth and the name of the patient being consulted was only shown as a confirmation before continuing. The images above show a live system using hospital data (hence the censoring of the patient name in Figure 5.9). The reliability of the recognition of the fiducial markers used on the access card was very good, and was a standard part of the Microsoft Surface SDK 2.0.

5.8.1.2 The Document Viewer

The main interface screen was a viewer with three organizing modes, which could be selected using buttons along the bottom of the screen.

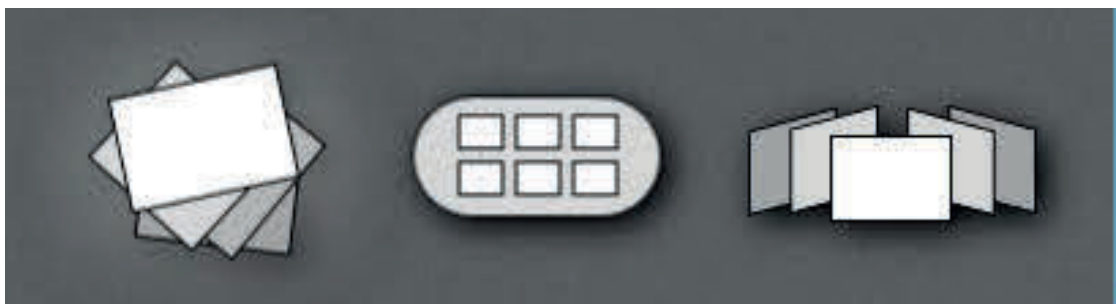


Figure 5.10: Buttons for selecting the three viewing modes.

The three documents organisation modes were based on observations of physical paper layouts used by doctors and nurses in hospital, i.e. 'spreading a stack of papers,' 'layout out the papers in a grid,' and 'leafing through the stack one page at a time.' Should the application ever be developed further and given a wider release, it would be worthwhile logging which metaphor and organization mode was most popular.

5.8.1.3 Digital Forms

Washington Hospital Centre, like many modern healthcare institutions, had a mixture of digital and paper-based processes in operation side-by-side. When

admitted, a patient's admission sheet and their identification and health insurance information are scanned into the hospital's central information system from a dedicated scanning workstation. Similarly, when the patient is discharged, the paper worksheet is filled and signed in pen, then scanned for storage and future access.

After some initial experimentation, a low-cost modification to a pen was found which created a means for signing forms directly onto the surface. This involved simply wrapping the curved end of a disposable pen with paper (see Figure 5.11, below). The paper reflected IR in the correct amount to be picked up by the Surface, mimicking the way IR light is reflected off a fingertip. With some modification to the code to create a uniform stroke thickness it was possible to simulate a very good ink effect. At the time, this was a completely novel means of input on the Surface, as pen input was not supported in any way. Although third parties had created active IR emitting pens, these would be difficult to recommend in the intended context, as they required batteries, are easily misplaced, expensive and more difficult to use.



Figure 5.11: Signatures could be captured using a modified pen in order to improve the efficiency of the documentation procedures.

Discharge documents were printed for each patient (as they were unique, reflecting the treatment they were given and contained treatment specifications). Doctors had bemoaned the unreliability of the printer and disliked having to refill paper and toner. It was estimated that being able to produce documents and sign them entirely on the Surface would save up to six pages of paper and up to eight minutes of time per patient. Patients would also be able to sign directly on medical images and other documentation such as radiography reports to confirm their accuracy or that they have seen and understood that information. Documentation and imagery could then be emailed to the patient or uploaded to their Microsoft HealthVault account.

5.8.1.4 Visual Reference Tools

Visual reference is a powerful way to communicate complex issues regarding physical conditions as they are often localised in a specific point in the body or involve several organs, which can be anchored in conversation by reference to a medical image.

A 3D rotatable mannequin with a separate dial for choosing modes to display either the skin, circulatory system, nervous system, major organs or skeleton was added for reference purpose. This was accessed by a button to the right of the screen which activated a 'drawer' which was semi-transparent so as not to completely lose the reference to the stage of progress with the patient's medical images underneath. This overlay window allowed for the visualisation to be invoked at any moment during the consultation.



Figure 5.12: The 3D model is shown with the circulatory system highlighted and slightly rotated and tilted.

Initial responses from the doctors indicated that they thought this would be a useful feature and requested further medical images (i.e. Gray's anatomical drawing, which were a favourite – possibly because they are commonly used in learning materials for medicine students).

5.8.2 Environment and Context

Following consultation with the head of the emergency medicine, the tabletop was positioned at the opposite end of the ward to the entrance, against an edge of the nurses' station, where the nurses have computer terminals and a desk to carry out administrative duties. This location was chosen so as not to obstruct the entrance or movement of the patients or doctors and to be close to a power and network point. It also allowed for the tabletop to be approachable from three sides whilst obstructing the 'top' edge – a design decision made to enforce the side-by-side seating of the doctor and patient to foster a collaborative environment, support a shared orientation and promote equal access by doctor and patient.



Figure 5.13: The Surface unit is positioned against an edge of the nurses' station, where many administrative procedures are carried out, such as the patient discharge procedure. It also provided power and network sockets and was unobtrusive.

The tabletop was covered with custom-made plastic cover which would protect the plastics of the main Surface unit from repeated cleansing with alcohol-based cleansers between uses and provide a continuous surface without the gaps between materials into which dirt could accumulate. This did not interfere with the operation of the table other than requiring slightly more pressure from the fingertips to operate.

5.8.2.1 Aims of the System

At this point in the development we were able to define what the task we were aiming to support was:

- An application for the doctors to explain the diagnostic process related to a patient's ER visit.
- To increase patients' understanding of their diagnosed condition.
 - It is hypothesised that the increased accessibility (i.e. number of entry points) of the tabletop will lead to a greater sense of control and shared ownership of the information being reviewed.
 - This may allow the patient to control the speed of presentation of materials and allow them to ask more questions when they don't understand something.
 - Also, the novel and visual nature of the application might increase engagement.

5.9 Feedback from Deployment

Unfortunately due to the nature of this project, and the limitations of my internship and visa, there was not much time or resource for conducting a lengthy evaluation. The tabletop and application were running in the ER for one week. During that time I demonstrated the application to many of the doctors and nurses on duty in the ward.

Feedback was universally positive: the doctors and nurses were able to grasp the purpose of the application quickly and agreed that it was a creative approach to the problem. They were also interested in the technology as none had seen an interactive tabletop before. However, everyone was very busy and didn't seem willing to engage in any training on how to use the application. In

total there was only one session run where the application was used as intended, and this is described below.

5.9.1.1 Case Study

A patient who came in with complaint of pain in her back and lower abdomen was tested and the lab results pointed to a kidney infection. She was helped to discover the connection between her diagnosis and the symptoms she was experiencing. The doctor explained why the pain was located in her back using the on screen model and the connection with her embodied experience.

Although the doctor was aware that the tabletop was designed to be used with two chairs side-by-side he preferred to stand. This points to a faulty assumption in the design: namely that the doctors prefer not to sit with the patient as they are generally too busy. A flexible solution where the doctor and patient could either stand or sit depending on the needs of the situation might have been more suitable. In this case, the manner in which the patient is sat and the doctor is stood and leaning over her produces a sense of imbalance. My feeling is that the doctors prefer to keep a slight social imbalance in order for them to feel more comfortable in doing their jobs.



Figure 5.14: The doctor shows the patient her lab results.

Initially we see the doctor and the patient both attending to the material on-screen. The lab report widget showed the patient's measured blood panel in an interactive list. Abnormal results were shown at the top of the list and highlighted in red. Tapping on a row in the list expanded the row to show the measured value and the normal range. In terms of the collaborative style here, the doctor is leading the interaction and both people are engaged with the material on screen 'in the interface.'



Figure 5.15: The doctor and patient look at the blood count and notice a 3x elevation in one marker.

Next, the doctor turns to the patient and explains that this measurement is what led them to form a diagnosis on her condition. He has turned to her to explain this and she is still looking at the screen. She puts her hand up to the table as if to indicate that she is taking this information on board and wishes to pause at this point in the conversation. Were it not for the tabletop, the doctor would have most likely been showing these results to the patient in a printed form on the doctor's clipboard. It might have been more difficult for the patient to indicate their level of comfort since the clipboard belonged to the doctor, so they may have held back from pointing at or touching it.

At this point, the patient raises the question as to why she had back pain. The doctor, being familiar with the interface, is able to move seamlessly between on-screen representation without disengaging from the conversation with the

patient. A button on the right edge of the screen brought up a panel with an interactive 3D model of the human body. A dial allowed for changing the representation between models of the nervous system, the cardiovascular system, major organs, skin surface, and skeleton.



Figure 5.16: The doctor brings up the 3D model.

The doctor is able to spin the model around to show the back. The model is displaying the internal organs and shows the location of the kidneys.



Figure 5.17: The doctor is able to use the model to build a connection between what is being described using the model and the patient's embodied experience.

At this point, the doctor is explaining that the kidneys are higher up towards the centre of the back than most people realise, and that because her kidneys were infected, she was experiencing discomfort in this area. This is why she believed she had hurt her back. He is explaining how they were able to rule out appendicitis which was one of her fears on admittance. The patient, mentioning her appendix, points to her left side, and the doctor corrects her by pointing out that her appendix is located on the right side of the body.



Figure 5.18: The doctor is looking at the patient as she describes where she thought her kidneys were placed.



Figure 5.19: The doctor is explaining what kinds of sensations discomfort in these areas is associated with.

The doctor is able to use the on-screen representation to mediate a delicate interaction where he is touching the patient to illustrate the point that her kidneys and appendix were not where she believed them to be.



Figure 5.20: The doctor uses the table to rest paperwork.

The doctor then takes the opportunity to use the tabletop as a surface to rest the paperwork that they need to review. The patient is being prescribed some antibiotics for her kidney infection and the doctor explains that she must complete the entire course of medication and not stop just when the symptoms abate.



Figure 5.21: The doctor points out some important information on the printed material.

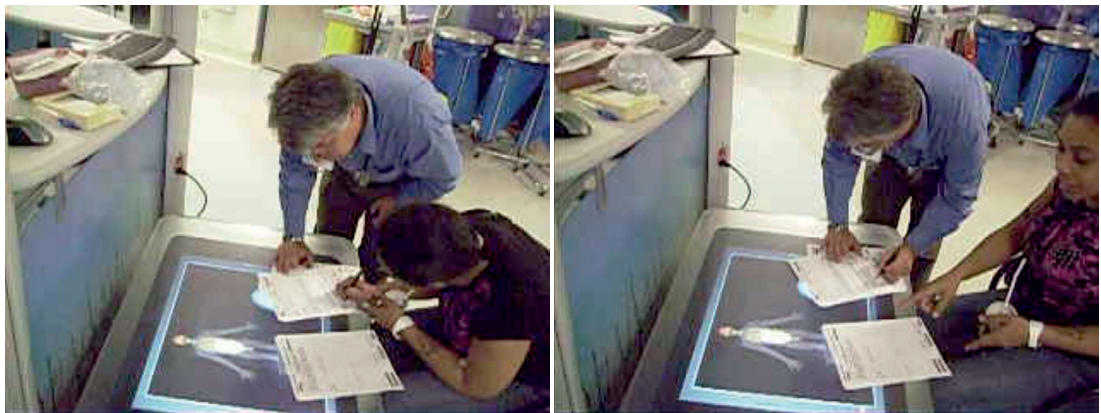


Figure 5.22: The patient signs the form and indicates that she enjoyed using the tabletop system.



Figure 5.23: The patient, when asked, says that the application helped her understand her diagnosis.

Feedback from the patient was positive and she said that the application helped her understand her condition. She also said that she would like to use it again, if she were to return to the ER at a future time.

As mentioned previously, the doctor in the above figures is seen standing over the table while the patient is seated. This is possibly due to the fact that time is short in ER visits and it may have been a fundamental error to assume that doctors and patients would have time to sit together to go over the educational material. For future designs a focus on shorter interactions might prove beneficial.

5.10 Discussion

In Figures 5.15 and 5.16 it can clearly be seen that the doctor is able to move easily between using the list of labs results to support a discussion of the diagnostics process which was carried out and to using the anatomical model to further expand on the physical causes of the symptoms the patient was experiencing. Moving between representations ‘fluidly’ and without interruption allows the higher order goal to be expressed. This was one of the aims of the interface design.

Due to time constraints and other restrictions I was unable to carry out further evaluation. The prototype application has been used in several promotional films for Microsoft as an example of how their vision for future technologies has real-world applications. The codebase for the application is now owned by TexasHealth, a Microsoft partner. The continued interest in the prototype therefore supports the notion that the design was successful, as far as it was developed.

The major barrier to adoption experienced in the deployment of this design was the availability and ‘buy-in’ of the practicing doctors in the ER ward. This factor is mentioned explicitly by Peter Jones in his book on designing technology for healthcare applications (2013):

“Disruptive innovations that we see in other industries may have less of a role in healthcare, even though the opportunities for new technology are clearly present. Healthcare facilities are not early adopters. New software, devices, and systems take time to learn and socialize, and the investment of professional time and budget in training and ramp-up is quite expensive.

The expense of these social costs can outweigh the benefit of adoption. For example, desktop computers took years to infiltrate hospitals, and by the time they were ubiquitous in the clinic, they had become common in homes. Minimal training was necessary because the technology was already pervasive. The use of mobile devices is following the same late adopter cycle, allowing for a more natural (less forced) introduction of new devices into high-performance, high-risk clinical environments...New systems are not always the answer. Consider the cumulative impact of the thousands of cognitive interactions required of users for every new service, system, interface, device, or billing statement. Doctors are too busy to adopt more than a few essential services, and they often maintain older systems that are safely committed to memory, rather than invest time in learning a new system that may introduce transition risks and fail to improve care or costs."

– Jones, P. H., 2013, Kindle Locations 589-592.

A related study in HCI innovation in healthcare by Ni *et al.* (2011) found that making information more accessible by patients could have a positive impact on the success of educational efforts. In their study on physiotherapy patients, Ni *et al.* found that projecting anatomical models directly on to patients' bodies led to a significant improvement in the level of understanding of their condition and treatment plan. A major factor was patient 'buy-in' to a course of treatment, which is to say the level to which the patient understood and was committed to a treatment choice. It was hypothesised that the direct and visual nature of explaining the diagnostic choices using their projection system led to a greater degree of internalisation of these choices and engagement with the treatment plan.

Similarly in the HealthTable application, there was some evidence to support that increasing engagement and deep understanding of the condition and treatment plan will help to bridge the communication gap between doctors and patients and improve patient outcomes.



Figure 5.24: AnatOnMe, by Ni et al., 2011, showing projected muscle layers on a physiotherapy patient.

In terms of the stated aims of the application, we believe that the HealthTable design was at least partially successful and showed promise for further development.

5.10.1 Future work

The major failing of this HealthTable study was that we did not succeed in attracting many doctors to use the system voluntarily. To address this, HealthTable could be easily modified for deployment in other areas of the hospital such as pre-surgery education or cardiology (viewing cardiograms would be well suited to the tabletop, with its intuitive zooming and navigation controls).

Thus, for a follow-on study, changing the context, task, and user group would be interesting. This would enable comparison and reveal insight into how the

success of tabletop interventions can be mediated by subtle choices of application area. It would also be interesting to further explore the fluidity aspect of the interface by using an extended design methodology – in particular to take into account the context of the next deployment area.

Although we were extremely fortunate to gain access to a context that is very hard to conduct studies, this also led to many constraints such as access to doctors. Delays in getting the system deployed *in situ* weakened the evaluation. Choosing other areas where access is not so tightly restricted may result in better evaluation performance. This could include other areas related to hospital medicine or private practice. For example, it would be interesting to explore different interface design solutions and to be able to compare and contrast.

Where studies are conducted in healthcare settings, access, privacy, and operational priorities can hamper research, as echoed by Peter Jones:

“Ethnographic or field research is hampered by limited access to the different “users,” especially patients, due to privacy and immediate care considerations. Most research studies take months, not weeks, because they are carefully designed and then reviewed by ethics boards.”

– Jones, P. H., 2013, Kindle Locations 633-635

The next three chapters go on to describe a later study with a different user group and set of tasks, the choice of which was partly informed by the HealthTable study. In particular, the choice in CamPlan to have a public walk-up-and-use setting allowed us to gather much more evaluative information than in the HealthTable study, because of the greater number of potential users.

CamPlan also has a different task, collaborative planning rather than collaborative learning. By studying two different collaborative task types it was hoped that a richer picture of the effects of tabletop design on collaborative tasks could be drawn.

6 Study 2: CamPlan

As mentioned in the literature review chapters, *in situ* research on multi-touch, multi-user systems is still in its infancy. Studies such as those conducted by Microsoft Research in Cambridge (*TellTable* and *Family Archive*) have focused on the effects of bringing a new technology into an existing social group with well-defined roles and practices, such as a school or family. Others have focused on walk-up-and-use media browsers designed to be used by groups or individuals.

This study aims to explore the potential of walk-up-and-use tabletop systems in public spaces. This contrasts and complements previous work such as Museum studies, and is in-line with the existing uses of tabletop technologies, such as in retail or hospitality. Building on the design methodology of the previous study, which was a Lean Observe-Build approach, this prototype was built to serve a real-world need identified through ethnographic-style observations, and refined through *in situ* testing and improvements.

Our goal with CamPlan was to explore the issues and opportunities of a shared tabletop system designed to be used by a coherent group of people carrying out a planning task. In this case coherent refers to the fact that the group is formed before they arrive, operate more-or-less in the same group configuration, and leave as a group.

Tourists visiting the Cambridge Visitor Information Centre were an appealing population to study. Initial observations suggested that many groups visit the centre with a need of planning their day trip or stay in the city. Often, they are

interested in finding out what the city has to offer, seeking inspiration for activities and sights to see, and assistance in planning an itinerary based on their available time. Posters and leaflets are available for them to peruse, as well as four PC kiosks which let visitors browse the Cambridge tourism website. Counter staff are on hand to answer questions, sell maps and arrange travel and accommodation.

The centre is located in a room large enough to accommodate the Microsoft Surface and people surrounding it. Our goal was to place a walk-up-and-use tabletop in the centre and design and evaluate a stand-alone planning application that enabled groups of visitors to find and share information and then plan their activities.

The interior design and representations of information often made it difficult for groups to create the spatial configurations that would enable them to orient with equal access towards a shared source of information (c.f. Kendon, 2010). For example, the long straight shape of the counter could make it difficult for more than two people to focus on information being discussed with a counter assistant. Similarly, the small size of the books, maps, and leaflets on which tourist information was provided and the lack of surfaces where these artefacts could be laid out and compared restricted the potential for focused face-to-face discussions.

The intention of this study is to understand how to design multi-user systems that are successful in the wild, and have to potential to be successful in the long term. Balestrini *et al.* (2014) note that "apart from valuable examples such as the Blacksburg Electronic Village...there are very few descriptions of HCI

projects that demonstrate long-term community engagement.” p. 2675.

Similarly to Balestrini *et al.*, an action research approach seemed appropriate for this study. The researcher conducted observations, and designed *in-situ*, solving problems progressively, as Denscombe (2010, p. 6) notes, to solve a particular problem and produce guidelines.

This participatory approach extends to inviting non-research stakeholders and subject matter experts to participate in the design and iteration of the solution. As Balestrini *et al.* state, citing Crabtree *et al.* (2013), “participatory approaches, where the community is involved from the outset, are crucial to the development of innovative interventions in situ, that foster sustained community engagement, and facilitate the use and appropriation of technologies.” This approach was used in this study, and is described in this chapter, and the following chapter.

6.1 Existing Tourism Studies

Previous research into developing technologies for tourism has focused largely on providing visitors with mobile and augmented reality applications that can be used outside the tourist information centre, such as recommenders and guides (e.g. Brown and Chalmers, 2003). Research inside tourist centres has focused on the interactions between staff and customers—the mechanisms employed in queuing and working across the counter—as well as the importance of paper representations, which can be annotated, re-orientated and shared (Brown, 2004). Rodden *et al.* (2003) conducted a study using a prototype which allowed for families to plan holidays, but this was mediated by a travel agent

and did not use touch-screen technologies. It was not possible to find any evaluations of shared tourist applications specifically developed for group use.

6.2 An Agile Approach to the Requirements and Design of the CamPlan Application

The approach employed for this project has been dubbed Lean Observe-Build. It is an ethnographically-informed approach, but this approach to making ethnographically-based observations and requirements and design is to interleave observations with initial design thoughts and 'change of lens.' The lens in this case is in the mind's eye of the observer-designer. By imagining a variety of potential solutions, the designer-observer is able to 'change lens' and pay attention to a variety of salient factors. This contrasted with a conventional approach of using ethnographic findings, which is to write up a full narrative of what is observed and then list a set of design implications or requirements derived from it. Being present in the environment triggers the design ideas that can become lost before having a chance of being explored and furthermore they can trigger different ways of seeing actions and interactions in the space.

Hence, by Lean Observe-Build it is meant that taking unexpected observations can lead to novel design thoughts *in situ* and, conversely, initial design thoughts can lead to a new lens for informing the observations. This can avoid some of the pitfalls of existing in-the-wild studies where interface issues and lack of interest from the intended audience hampered both the experience for the users and the quality of research. The approach is broken down into ethnographic-style observations of a potential site for deployment, active participation in the

target community with continuous design ideation and the elicitation of requirements for the focused design process described in the following chapter.

In total, there were five stages involved in the design and development of this application:

1. Initial ethnographic-style observations meshed with design thoughts including an embedded day of active participation to elicit requirements.
2. Ideation and brainstorming, producing sketches, discussed with stakeholders.
3. A focused design workshop in which key interaction methods were brainstormed and compared, and rapid prototyping used to accelerate development.
4. User testing with an interactive computer prototype
5. Continuous development during deployment.

1) and 2) are described in this chapter, with 3) to 5) being discussed in the following chapter. The activities undertaken included the design, implementation and evaluation of a tabletop application, which was situated in a busy visitor information centre for a period of six weeks. Evaluation was carried out using several methods including logging, observation, interview and video analysis.

6.2.1 Introduction to the 'CamPlan' Study

With assistance from my colleagues, I designed, implemented, deployed and evaluated an application for multi-user group planning on a tabletop platform in a public space. My contribution was to design the application and the approach

taken, contribute significantly to the graphic design and code development, and conduct the initial ethnography and contribute significantly to the evaluation observations. Because of the need for the hardware to be robust, the Microsoft Surface was chosen. The purpose of the application was to assist tourists who came to the Visitor Information Centre in Cambridge, UK. The Visitor Information Centre (VIC) is located in the centre of the city and is broadly similar to the tourist information offices found in many cities.

The choice of this domain (travel and planning) was, among other factors, inspired by earlier work on collaborative tourism planning conducted as part of the eSpace project by Yvonne Rogers and her colleagues, which demonstrated the usefulness of an interactive system in this domain (Rodden *et al.*, 2003; Sharp *et al.*, 2007). In that project an interactive system was devised whereby a cohesive, preformed group (e.g., a family) could sit down in front of several screens and work with an expert (the travel agent) in choosing amongst the numerous travel options. The system provided a means whereby they could see the impact their choices were making on the time and cost of their holiday plans.

The eSpace system was an example of Multi-Display Groupware (similar to Single Display Groupware (SDG) but with several screens). This was shown to be an effective tool for enhancing group planning. The application designed for the Cambridge VIC, however, was different in several respects. Firstly, it was built with a different technology, a tabletop (Microsoft Surface), which afforded simultaneous interaction by several users and multi-touch gestures. Secondly, the application was intended for use by a family or other cohesive group on their own, without the aid of an expert user. Thirdly, it only featured attractions

and sights in the centre of Cambridge city such as could be visited on foot in a day, as opposed to a multi-city or multi-day journey. These factors, along with other design principles (such as trying to keep the whole interaction down to five minutes per group) were developed from extensive ethnographic-style observations of activity in the VIC by myself, with assistance from my colleagues.

6.2.2 The Cambridge Visitor Information Centre (VIC)

The Cambridge Visitor Information Centre is located centrally in the city of Cambridge, adjacent to the main market square and amidst several of the city's famous colleges. During peak months (June to August), footfall in the centre can reach up to 2,000 visitors per day. This includes many groups, families and bus tours. Up to five Information Assistants are available to help and normally work from behind a counter. The VIC is part of a tourist hub which covers four rooms including the VIC itself, where the Information Assistants are located along with maps and brochures, a gift shop, which also sells maps and guides, a media gallery which, at the time of the study also had regular interactive shows, and a café. An overhead schematic of the VIC is shown in figure 4.1 and photos of the centre are shown in figures 4.2 and 4.3.

Access to information in the VIC was roughly split between two categories: 'self-serve' information and 'assisted' information. The 'self-serve' options were on the right of the entrance and were coloured burgundy, whereas the 'assisted' information was demarked by the blue coloured boards and the counter and staff (who wore blue shirts) to the left of the entrance. Blue and burgundy were

chosen as the official colours of Cambridge University and the Cambridgeshire council.

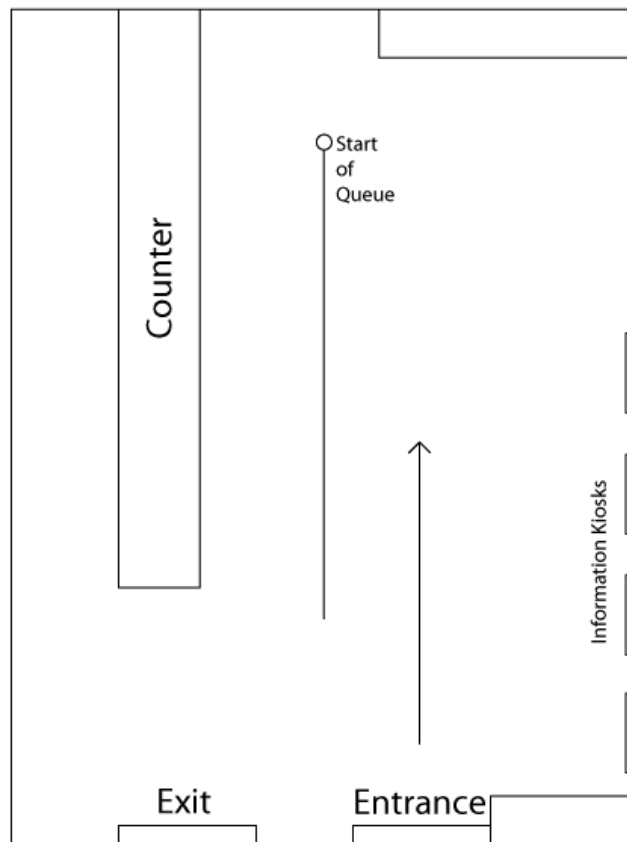


Figure 6.1: Overhead schematic of the VIC.



Figure 6.2: Interior of the Cambridge VIC from the entrance.



Figure 6.3: View from the front of the queue, showing the Information Assistant counter and the exit.

The counters were designed to be low and wide. This served several functions, the low height made them wheelchair accessible and 'open and friendly'. They also allowed the Information Assistants (IAs) to work either sitting down or standing up. However, they were wide to protect the IAs by placing them out of arms reach of hostile visitors (of which there were a surprising number) and the magazines, cash till and other valuable resources apart were on a bench far behind the counter. At peak times, queues were managed by an automatic queuing system and the visitors ('customers' as the VIC refers to them) were aligned to queue along the rope along the middle of the VIC.

Design thought: Observing visitors queuing led to a design idea for the positioning of the tabletop. As people were waiting in the queue to speak to the assistants they would have opportunity to observe the tabletop and other users. Initially, the director of the VIC had suggested placing the tabletop outside in the hallway, however, on observing this and considering the work by Brignull & Rogers (2003) on thresholds of attention and interaction and the 'Honey Pot' effect, I was able to suggest that a more visible position which allowed people in the queue to observe others using the system would lead to more interaction and a more successful system. This was found to be so and visitors would sometimes leave the queue to interact with the tabletop. This is discussed further in the observations and analysis in the next chapter.

6.2.2.1 Wall Boards

On the four walls of the VIC there were wall boards attached above the wooden panelling. The wall boards were quite high, putting the upper racks of brochures out of reach of many visitors, but had to be so as the wooden panelling was

protected by the heritage status of the building. Local businesses could pay to have their brochures in the racks on these wall boards and these were on the right hand side of the entrance (see figure 4.4). Towards the far side, opposite the entrance, were wall boards with posters displaying information about local events and concerts, as shown in figure 4.5. Behind the counters, to the left of the entrance were boards which showed information about the centre and promoted several tours, such as the bus and river tours. Between the entrance and exit was a large map of the city and surrounding area.



Figure 6.4: Wall boards are also used to display brochures and posters of local attractions.



Figure 6.5: Information is displayed on wall boards showing current events.

Visitors who used the wall boards would either browse casually, looking for things to 'jump out' at them or would take a direct approach by either picking up leaflets for certain activities they appeared interested in or picking up several brochures, seemingly with the intention of reading and surveying as much material as is available. It was not uncommon to find visitors grabbing handfuls of leaflets and brochures and then reading them off to one side or sat on the small benches at either end. A handful of brochures would represent a lot of information and would be quite cumbersome to hold and sort. If visitors

came in alone it was common to see them scan the brochures and put the ones which they did not want to keep back in the racks or leave on a surface. Having reduced the set of brochures down, they might read the remaining ones more carefully then decide to leave the centre, or go to the counter to ask where the attractions were located. If the brochure-collecting visitors were with other people they might recouple to show what they have found and discuss the options. Similarly, they would discard options which were mutually disapproved, then leave with the brochures or go to the counter.

The height of the wall boards meant that some visitors were unable to reach the higher racks. Once or twice this did lead to an interaction whereby a visitor would ask someone nearby who was taller to help them. For example, a conversation overheard went:

A: "Could you hand me one of those brochure up there, please?"

B: "Sure... this one?"

A: "Yes, thank you very much."

This conversation was very polite but never progressed beyond the brief request, which is typical of when strangers ask a favour of someone else standing nearby.

Design thought: A system for using the brochures as tangible artefacts with the tabletop was considered. Camera-based tabletop systems such as the Microsoft Surface make it possible to interact with the tabletop system using external tangible objects marked with fiducial codes. In this application, it was considered that one way of accessing information on the tabletop and extending this interactively would be to print fiducials with unique IDs on the back of the

brochures (fiducial markers were used in the deployment of the hospital study in this course of research with personnel identification cards as discussed in chapter 6). When these would be placed down on the tabletop extra information could be displayed including location on a map and that attraction could then be added to the users' itinerary. For non-camera based tabletop systems (such as FTIR systems) RFID tagging could provide similar functionality.

This approach was rejected for several reasons. Although it would provide a novel and engaging interaction method, which has been used in laboratory studies, an initial pilot survey indicated that this would be very unintuitive in a public environment without the benefit of laboratory demonstrations.

As an in-the-wild study, it was important that we consider what interaction paradigms the users might be familiar with and to employ a very obscure method would reduce the overall effectiveness and utilisation of the application. Also, the brochures are a key characteristic of the centre and something visitors would expect to find. Since the brochures were printed by companies that paid for display in the VIC, it was considered not practical to interfere, as well as the fact that thousands of brochures were taken each week and the range of brochures was constantly changing.



Figure 6.6: A large OS-style wall map is provided although the scale is not ideal for people interested in the centre of the city. Printed maps of the city centre cost 50 pence from the counter.

The large wall map gave a good indication of the scale and location of the surrounding towns and also held transport information brochures. However, this map was not useful for those wishing to visit the attractions in the centre, which described most visitors. Maps of the city centre were available to buy for 50p from the IAs at the counter.

Observation: Considering the maps in the VIC led to considering how people use the different kinds of maps. A large-scale map of the area might be useful for giving a geographical context to the town, showing the course of the river, for example. However, a more useful scale of map for people on foot in the city centre was only available by interacting with the IAs at the counter. This made the maps an active resource and an opportunity for visitors and IAs to interact. In what ways might it be possible to augment the map and include information

from the brochures? How would it be best to support group interaction with this representation? Would different users use a digital map representation in different ways (e.g. children vs. adults)?

Design thought: Given the importance of a map representation, I considered whether a map should form the central interaction method for the planning application. Perhaps the visitors themselves could annotate the maps at the tabletop by marking attractions of interest, for example. This representation could then be used with an IA as a point of reference to refine a plan, or serve as an adequate plan by itself.

6.2.2.2 Information Kiosks

The VIC already had four upright PC-based information kiosks which were positioned against the wall to the right of the entrance. They were situated between the wall boards so as not to obstruct access to the brochures or the queue. The default screen for the kiosks was a blue screen with several pictures which could be clicked on using the trackpad, which would take the user to either the visitcambridge website⁵ or Cambridgeshire council websites.

However, it was not immediately clear how these options were to be chosen and hence not entirely intuitive. A single user could interact using the integrated keyboard and track pad. Occasionally, other visitors would read over the shoulder of the person using the kiosk, choosing then to start interacting with another kiosk or passing on.

⁵ www.visitcambridge.com

Design thought – Children and teens were drawn to the kiosks but typically only used them for a short time, after not finding anything useful quickly. Also, the web-based system does not support perusal of multiple alternatives in the way that holding several brochures can. How could one make this comparison mode of searching possible at the tabletop in the way brochures are used like a fan of cards?

It became apparent that the brochures were a powerful means of embodying information in a shareable, sortable and cheap fashion. However, they were cumbersome to browse, not directly searchable and contained a limited amount of information, requiring assistance from the IAs to locate them on a map, for example.



Figure 6.7: PC information kiosk, showing default home page.



Figure 6.8: The kiosk shows the visitcambridge website.

I chose not to use the kiosks as a platform for the group planning application, as they did not offer an accessible means for group interaction. Their orientation tended to produce a configuration whereby one user would become the ‘driver’ of the collaboration, similar to the configuration found in Rogers & Lindley’s (2004) study on vertical and horizontal shared displays. One of the main research goals for this study was to investigate new forms of interaction and it was felt that the PC kiosks would be approached by users with a host of expectations from using traditional PCs elsewhere which would overly constrain the range of possible interaction styles.

Additionally, from observations of typical activity across the VIC, the main artefact that visitors sought for and left with was either brochures with information about specific attractions, or a map with annotations made in consultation with the IAs, or both. The kiosks, which were not connected to any printer, did not support these representations.

Design Thought: What if a tabletop application could provide user groups with printed artefacts to take away? Could those artefacts potentially offer combined benefits of maps and brochures in a user-customisable way?

6.2.2.3 The Information Assistant Counter

A large proportion of the visitors to the centre went to the IA counter. The IAs were skilled in dealing with the needs of the visitors and knowledgeable about Cambridge, with most of them being residents of the city. Before a visitor walked up to the counter, the IAs were normally able to judge what they were likely to require based on several factors such as time of day (visitors in the evening were typically looking to book accommodation), whether they were in a

group (sometimes large groups would enter and the group leader would head to the counter to seek information and make bookings) or their body language (some people would stride in confidently seeking a specific piece of information whereas others would approach more hesitantly and require more general information and suggestions as to what to do). When it seemed appropriate, it was common to see the IAs reach for a copy of the map before the visitor has even reached the counter, as providing a map with some annotations giving orientation and suggestions for the more popular attraction was the most common type of interaction between the IAs and the customers. The subtle act of the IA reaching for a map in these cases gave confidence to the hesitant visitor – bypassing the need for them to ask for the map, and accelerating the interaction.

Some visitors seemed surprised that the VIC charged 50p for the map, but none refused to pay. The need to charge for maps has come about through the fact that the centre receives far less public funding than in earlier times and now has to generate most of its revenue to keep covering costs. By designing a system which provided visitors with a map and information, while being useful to the centre, was potentially removing a source of income as visitors would be less likely to purchase a second map. This was addressed in a way which also provided an interesting research angle. By placing a donation box next to the printer, it was hoped that people would make a donation when they collected their printout, in a similar way to how transparent donation boxes are placed at the exit of some museums.

A sign saying ‘suggested donation of 50p to cover printing costs’ would be placed next to it. It was assumed that after investing a certain amount of time in

the application, making a small payment at the end would seem more palatable, as well as the fact that lots of technology users are comfortable with making micro-payments in mobile e-commerce. This approach would also give us a proxy way of estimating how valuable the users found the experience to be, with the assumption that the amount donated would reflect how satisfied they were with the experience. This approach has not been used in tabletop research before. We could not make a fixed-price system as the additional complexity would discourage users and slow down the research, as well as becoming an

issue for gaining ethical approval. All

money collected was given to the VIC.

Examples of the popular sights which IAs suggested are King's College Chapel, the Market, 'the Backs' (the backs of several large colleges along the river, which offers pleasant walks and impressive vistas) and any events happening that day (which usually included choir rehearsal or performance in King's College Chapel).

At the time, the VIC was also running a new attraction in the adjacent room which was part photo story and part live-action drama which was meant to give visitors a humorous introduction to the city. Tickets and advertisements for this were promoted heavily in the VIC.

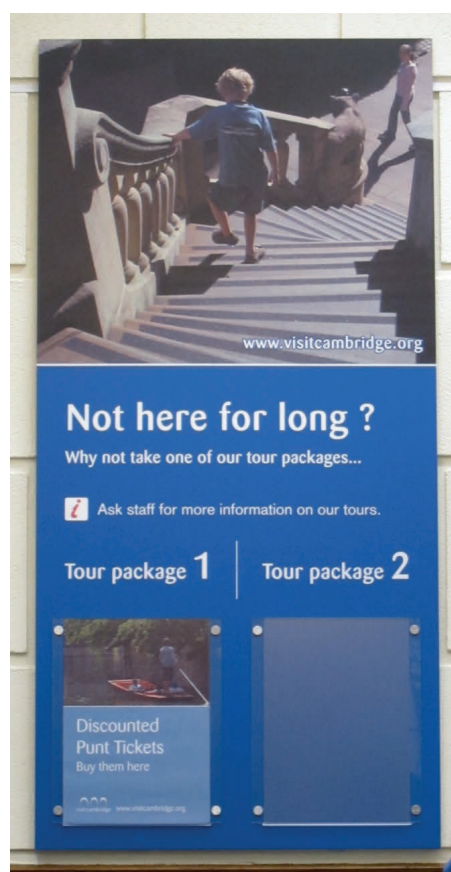


Figure 6.9: Certain tours, which are a revenue source for the VIC, are prominently advertised by the counter.

Figure 6.9 shows a large wall board promoting the tours available from affiliated companies for purchase through the VIC. These tours are popular and are positioned as a way to sample the city for visitors not staying for a long time. Figure 6.9 above shows one poster for the punting river tours, and normally shows another tour, such as the bus tour, another river tour or guided walking tours which leave from outside the VIC. Sales of these tours are crucial to the centre as they are a significant revenue source since a proportion of the sale is returned to the VIC as sales agents. The tours also help promote the city as they are higher quality than some others available. The wall board is positioned at the side of the counter, which makes it easy for the IAs to refer to when making suggestions for visitors.

Overall, the VIC was laid out with a lot of thought. The above sections are intended to illustrate how designing a novel application for deployment in the wild is different from designing for other purposes, such as lab studies. Whereas general design ideas and approaches can be used to great effect it is crucial to consider the entire system into which this technology is intervening and considering how it will affect existing practices and how it will be accepted and integrated into a new overall method of working. It shows how specific constraints can make certain options possible or impossible, how any solution must be robust and align with aspects such as aesthetics and revenue streams, and physical place and space. Below are some observations of the activities of the visitors to the VIC and, from this and the factors already mentioned, a set of initial requirements were formed.

As in any workplace, the IAs were of various levels of experience. The knowledge shared between them was vast. If a customer had a question that the

IA did not know the answer to, they would typically ask someone with more experience. After a while this would mean all the IAs would have knowledge of the most commonly asked questions. In the requirements gathering, I asked questions along these lines by querying IAs of different experience levels what questions they would ask / be asked, in order to ascertain what were the most common issues. At the time, no system existed to centralise these questions and log the knowledge, although this might have been beneficial to the centre and useful for this research.

6.2.3 Observations of Activity in the Visitor Information Centre

Following the success of the e-Space project, it had been demonstrated that collaborative tourism planning was a fruitful field for further investigation. To this end an ethnographic-style series of observations in the visitor information centre were carried out to assess whether it was suitable for a similar technological intervention. Initial observations were made over a period of five days, with a further five days conducted later, including a full day embedded with the Information Assistants behind the counter. Various styles of data gathering were employed; observation was the main approach, but interviews were also conducted on the basis of emerging findings from the initial observations. Acting as participant-observer behind the counter was also revealing, and highlighted the skill of the IAs in being able to respond quickly to visitors' queries, even when they are not entirely sure of what they are asking.

Some of the main findings are:

- the types of groups that come into the centre are varied. A significant proportion are families;

- the counter in the centre is a shared space that the assistant and adults talk at but which excludes children to some degree;
- many visitors prefer to look for information in the centre themselves rather than ask an assistant at the desk, possibly because they do not speak English as a primary language, are shy or do not have a well-formed idea of specific questions to ask and are hesitant to take up time being ambiguous or indecisive with the IAs;
- of those groups that do ask for information, usually one or two from the group will go to the counter while the others look around the centre. The group then reforms and shares information. This was similar to findings made by Marshall *et al.* (2011) in their ethnographic study conducted in a tourist information centre;
- they may use a variety of paper-based information resources to make a plan, including maps, leaflets, brochures, guide books and scraps of paper and tickets. Some people were observed to use their mobile phones for viewing maps and making notes; and
- the most common activity seen is individual information foraging with occasional comments or short discussions made one-to-one rather than in larger groups.

One of the interesting findings of the initial observations related to how visiting families behaved in the information centre. A common pattern was that the family group would split up on entering and break into fact-finding 'units' which would then take different approaches to foraging for information. For example, in the case of a family entering, the parents might split up with one going to the

counter to talk with the information assistants and the other browsing the posters and collecting brochures. If one of the children was old (and tall) enough they might use the PC-based kiosks but, generally, children were left out of the information-seeking process (for example by the height of the wall boards or counters). The benches were often used by one parent to sit with the children whilst the other parent went to the counter.

When the parents had completed their tasks, the family would reform and they would discuss what they have discovered and form a plan for their activities during their stay in the city, based on the available time, budget and interests of the group members.



Figure 6.10: Visitors to the VIC often split up and browse individually. Here, two ladies who entered together are separately browsing the brochures and the PC kiosk. The kiosk to the left is broken.

We also conducted interviews directly with the centre's staff, both front-line and back-office, to discover what their hopes of the interactive tabletop system would be. Feedback from the centre revealed several issues that they were concerned with:

- i) they were keen to promote activities to the tourists which had a revenue route back to the centre, such as guided walking tours or bus tour tickets;
- ii) they wanted to ensure that, since the table was being deployed at a peak time in the year, people would not loiter around it or that it become an obstruction to other guests.

We approached the second concern by deciding that we would design the application to be useable from entry to exit in an average of five minutes. Since the Surface is designed to be used whilst seated we considered adding a platform beneath the table to raise it by about 25cms so a standing adult could use it comfortably without bending. Compared to using chairs, this was considered to be an effective way of preventing people from gathering around the table for long periods of time and causing an obstruction, and to reduce the space requirements.

This then led us to consider how to make it accessible to all users, including young children. We considered adding some foot stands at the edges so younger users could reach the screen, but by only adding platforms to two of the four edges we hoped to indicate the intention for it to be used by adults and children together. Also, by putting the foot platforms of the side (shorter) edges, this left the main, canonical orientation (along the long side) unencumbered as well as

preventing the structure from blocking visitors passing to the side past the wall boards or on their way to the counter.

From this we formed an initial set of requirements for the application from several angles, encompassing the desires of the different stakeholders: the VIC's goals, the user's goals and our research goals. The goals for the user were:

- The application should assist a cohesive group of 2 to 6 users in understanding what options and attraction are available to them for their stay in the city and to help them organise and form a plan based on important information.
- To keep the whole interaction per group as streamlined and easy to use as possible and not to exceed 5 minutes average time from start to finish.
- To provide the group with a useful shared artefact to take away.

The goals for the VIC were:

- To be accessible and easy to learn to use for families with children or groups of adults.
- To be intuitive and direct – to excite and entertain with the new technology and interface whilst providing enough functionality to be suitable for its purpose.
- More specifically, to provide a printable map and additional information relevant to their choices which can either be taken away or discussed with the IAs.

- To promote and raise awareness of the tours and tickets which had a revenue stream back to the VIC.

Our research goals were:

- To investigate whether user-centred and agile methods can be adapted for the design of collaborative tabletop software, especially for in-the-wild use cases.
- To support different forms of collaboration, discussion and conversation to happen within different kinds of groups and to see how they transition from one form to another. For example, in a single session, to transition from working individually in a parallel fashion, to working closely with a shared representation.
- To encourage individual choices and refinement of the shared goal in separate stages.
- To encourage new forms of interaction, mediated by a novel interface.
- To gain an understanding of how people use a tabletop application for planning in groups.
 - Does utilizing a tabletop platform lead to more discussion and equitable outcomes?
 - Does utilizing a tabletop platform help make interactions more equitable between users generally, and between adults and children?

In addition there were general requirements that held for all stakeholders:

- The application should be robust and have a professional level of ‘fit and finish’ to encourage use and confidence and to avoid feeling like a prototype or discouraging users with software failures.

The initial requirements were then refined over a two-day user-centred design workshop. This was carried out with an external graphics and interaction designer, my colleagues Yvonne Rogers and Paul Marshall, and myself. Following this, interactive prototypes were created and tested with naïve users. This process of design, from the original workshop to the continuous development during deployment, is described in the next chapter.

7 CamPlan Design

In this chapter, the initial requirements gathering and design thoughts are parlayed into a series of design sessions. Both individually and as part of a creative group, the ideas for a multi-user planning application were developed and tested using a lean user-centred approach. The chapter begins with a discussion of the Lean Observe-Build approach and then continues to describe the design activities which took place between the initial *in situ* research and the beginning of deployment.

7.1 Design Iteration

Starting with the draft requirements gathered during the initial research activities, which included observation, requirements gathering and an early design phase for the application, a two-day workshop was conducted to develop the user interface and refine the application goals along with our vision of what research questions this project could address.

This chapter describes the focused design work carried out over a two-day workshop, a period of prototyping, two user-centred testing sessions and continued refinement and evaluation over the period of deployment, following the Lean Observe-Build approach.

This continues the approach pioneered in the work described in the previous chapter. The merging of observation, requirements analysis and interactive ideation, with the active participation of both the designer and other stakeholders is a process given the term 'Lean Observe-Design'.

This is an experimental approach intended to satisfy the demands of designing for in-the-wild deployments, and to allow for the richness of ethnographic-style observations to feed into the design in a flexible and self-aware fashion. This includes a focus on the aesthetics and the holistic user experience (integrated into its setting), which differs from the design approach typically used for lab-based studies, for example. It is essentially a User Experience (UX) driven process from a Service Design tradition, with the designer/observer acting as a 'UX champion', constantly aware of the overall environment and how the technological intervention changes this. This is thought to be crucial for tabletop development as the potential of this technology (as a multi-user platform) is utilised to greatest effect when the casual, but rich, social factors of collaboration are supported.

7.2 Design Facilitation

As mentioned in the requirements summary, an important requirement was that the application should be finished to a high standard so as not to feel like a prototype to the end users. It should allow for a natural interaction without their experience being hampered by lowered expectations or from software crashes. A professional interaction designer, Matt Davies of User-X, was recruited. Matt has experience in designing applications from mobile to multi-screen systems and had previously worked on the eSpace project. For this project, he served two roles – as an additional facilitator in the design workshop and as an additional graphics designer who was able to help contribute graphics resources. To increase the chances of members of the public interacting with

the tabletop application, it should appear to be high quality (Wallace and Scott, 2008).

7.3 Lean Observe-Build: a Design-observation cycle

Prior to the workshop, I had begun brainstorming several ideas and discussing them with colleagues and the VIC. The first challenge was to generate an idea for how to represent and navigate the information selected in consultation with the VIC as having high value to the users. In this application, this comprised a list of popular attractions, sites and activities located in the centre of Cambridge city. For each of these it was decided that information such as the name of the attraction, cost of entry, a description, opening hours and a photo comprised the basic representation to initially show the user to assist their browsing.

The ethnographic-style observations outlined above which formed the initial requirements were used as a basis for initial brainstorming and sketching. Some of the sketches are shown in the figures below. After discussing these sketches with staff at the VIC more formal representations were created, including 'sketch-style' computer-generated representations with descriptions intended to provide a sense of the overall user flow. Several different interface metaphors were considered in parallel, with some of these ideas surviving to the design workshop and being worked into paper prototypes, whilst others were rejected for various usability reasons or their suitability for the user and research requirements.

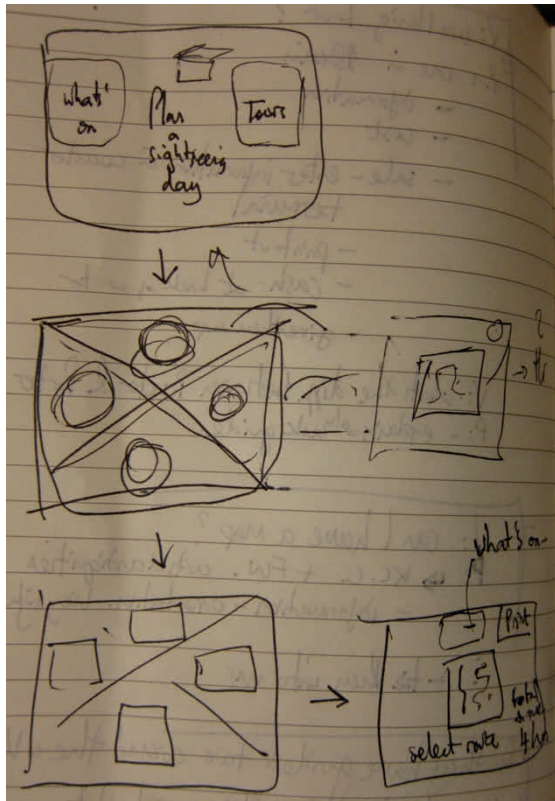


Figure 7.1: Early sketches of possible interface designs made during observations. Key features such as the four user 'quadrants' and the central map representation are present.

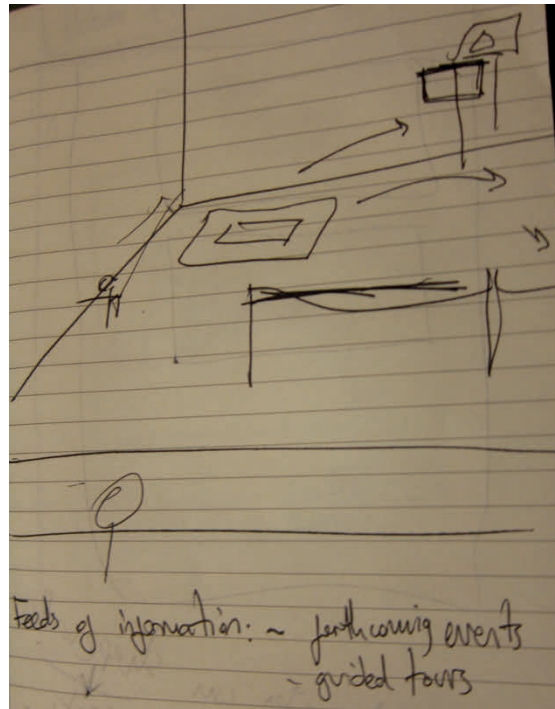


Figure 7.2: A sketch showing the imagined position of the Surface and printer, alongside the queue rail and out of the way of the counter. A critical decision in relation to this situated context was to ensure that people who completed the interaction re-joined the queue at the back in order to prevent possible disturbance, as shown by the arrows.

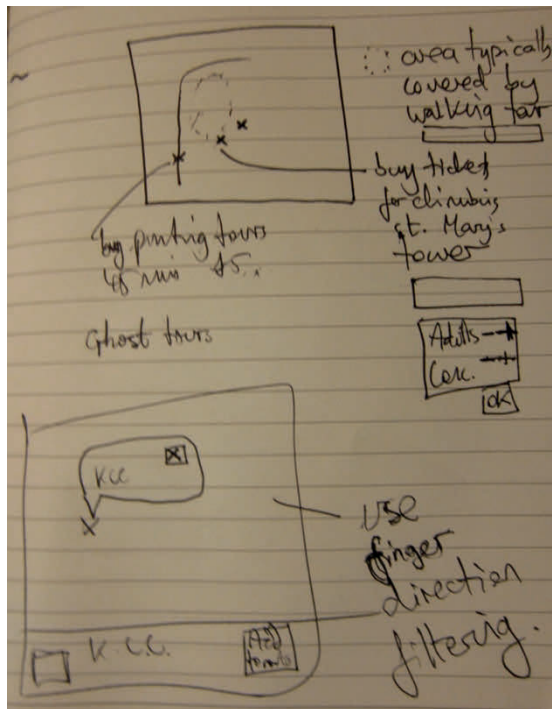


Figure 7.3: A sketch of an interface stage showing positions of attractions on map and how to access more information and add tickets for tours.

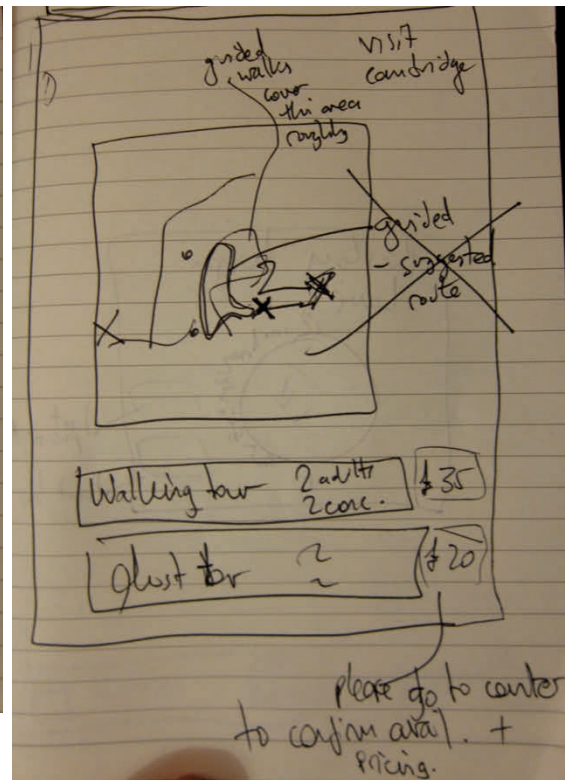


Figure 7.4: A detailed sketch of the paper printout produced by the application, including features such as the Visit Cambridge branding, the map with chosen attractions and a summary of the chosen tours and tickets with the reminder to pay at the counter.



Figure 7.5: A three-dimensional sketch of the tabletop positioned in the corner of the VIC.

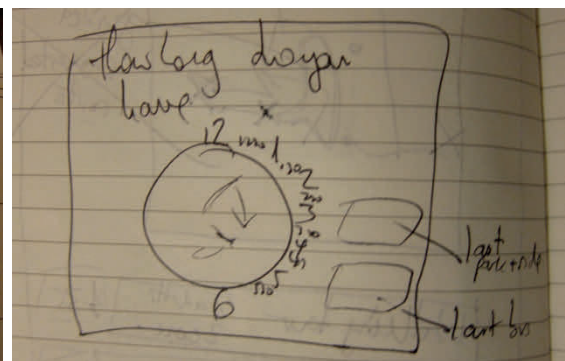


Figure 7.6: A sketch of a possible interface component in the interaction whereby users indicate how much time they have available for their visit.

Quick, low-fidelity sketches allowed for rapid visualisation and communication of ideas, allowing for immediate feedback and an iterative improvement. Being situated in the centre whilst designing, the sensation of how the technology and application would impact the current systems could be felt. It was important to evaluate the implicit assumption of each design idea and to explore alternatives, so as not to close a design 'door' prematurely.

After discussing the initial sketches with the stakeholders, more formal representations were made, which retained a degree of flexibility to enable open-ended discussion.

Figures 7.7 to 7.9, below, show a series of sketches indicating the intended user flow (a series of screens showing the phases of the interaction and the appropriate interface representation, along with the configuration of the users around the tabletop). Initially, with the assumption that groups would approach the tabletop at the same time, the users could then begin interacting with the screen (Figure 7.7) and then be guided through a series of questions designed to elicit responses (Figure 7.8) which could be used to then present a series of options in a map representation and changes made as a group (Figure 7.9).

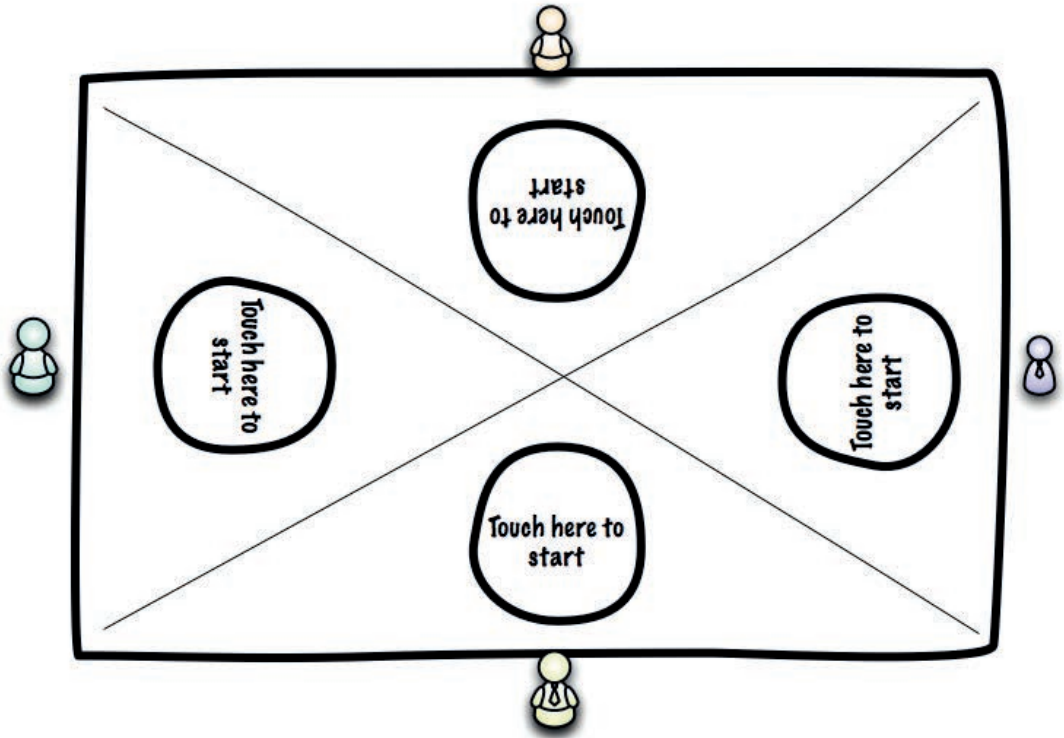


Figure 7.7: A medium-fidelity sketch of the initial attract screen.

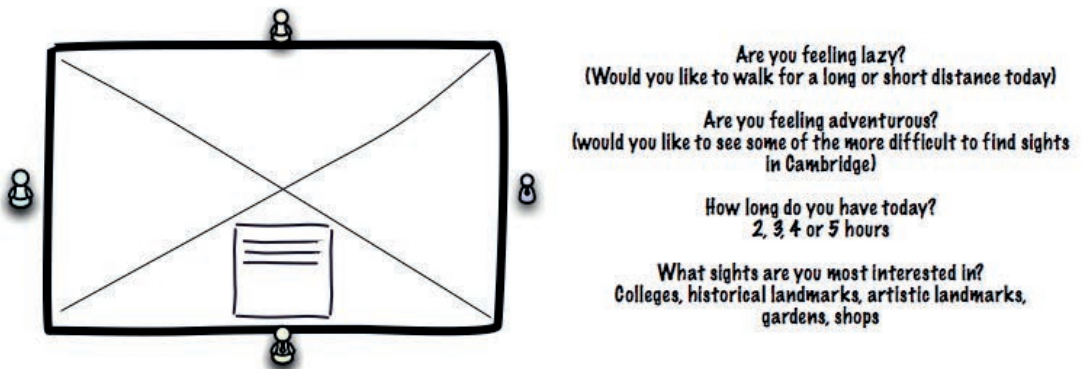


Figure 7.8: A medium-fidelity sketch of the individual questions delivered to the user in order to produce a customised list of attractions.

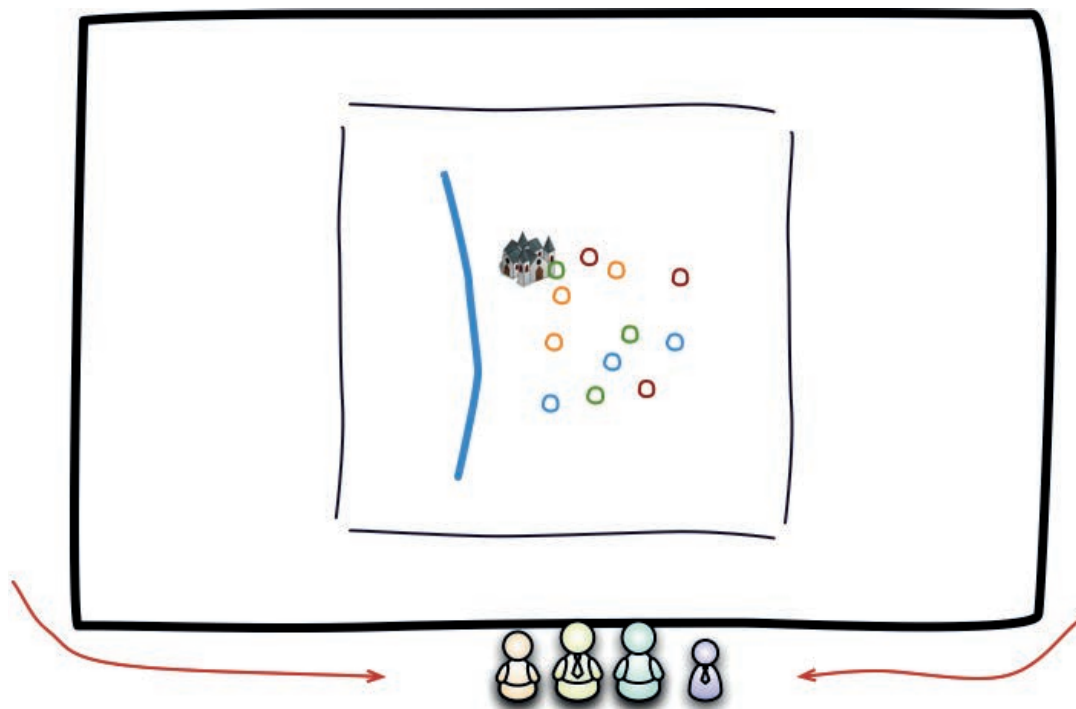


Figure 7.9: A medium-fidelity sketch of the final interactive stage where users' choices are represented on a map. The canonical orientation of the map is shown to guide the users to re-form at the 'bottom' edge of the screen.

Figure 7.9 shows how the users are imagined to move around the table to realign along one side of the table (the canonical view – i.e. as if the tabletop screen were a vertical screen). One of the research goals was to see whether users would perform this, based on cues of orientation given by a shared map and an increased amount of text, as opposed to the individual 'zones' oriented to different edges of the screen.

7.3.1 Consultation over Initial Sketches with VIC

As soon as the initial user flow and sketches were complete this was discussed with the stakeholders at the VIC.



Figure 7.10: A three-dimensional representation of the Surface tabletop with the additional step/stand and associated measurements. Also showing the separate printer box. 'Apr-May' is written down indicating a potential timeframe for the deployment.

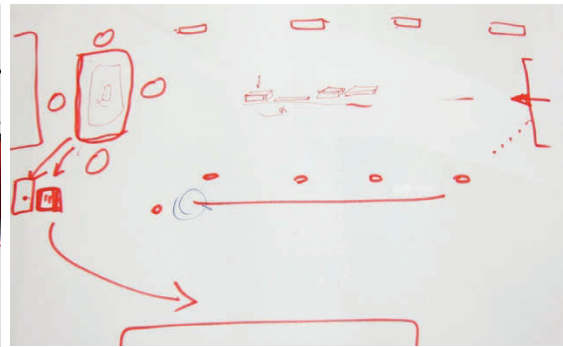


Figure 7.11: An overhead view of the VIC with the entrance top-right. One alternative for the positioning of the tabletop and printer is shown, indicating how users can access the counter or the exit after collecting their printout.

Figure 7.11 shows an overhead schematic of the VIC with a potential position for the tabletop and printer added. In this drawing the printer is placed between the tabletop and counter, guiding users along a path towards the IAs, as an assumed natural next step in their visit to the centre. However, during the discussion, concerns were expressed that this might lead to a group of users heading to the front of the queue for the counter. This might lead to resentment from people in the queue who were not using the tabletop. The suggested position of the printer was therefore moved to the opposite wall, where it would define a movement towards the back of the queue, which was agreed as a more fair implied path.

The orientation of the tabletop was also important, as in Figure 7.11 it is shown being aligned alongside a bench on the wall opposite the entrance. This might have encouraged people to sit down for long periods of time while interacting with the tabletop. Rotating the tabletop ninety degrees and positioning it slightly further from the bench would, it was thought, remove this temptation

and better meet the VICs requirement of minimising the physical impact of the tabletop to the existing queuing and browsing patterns.

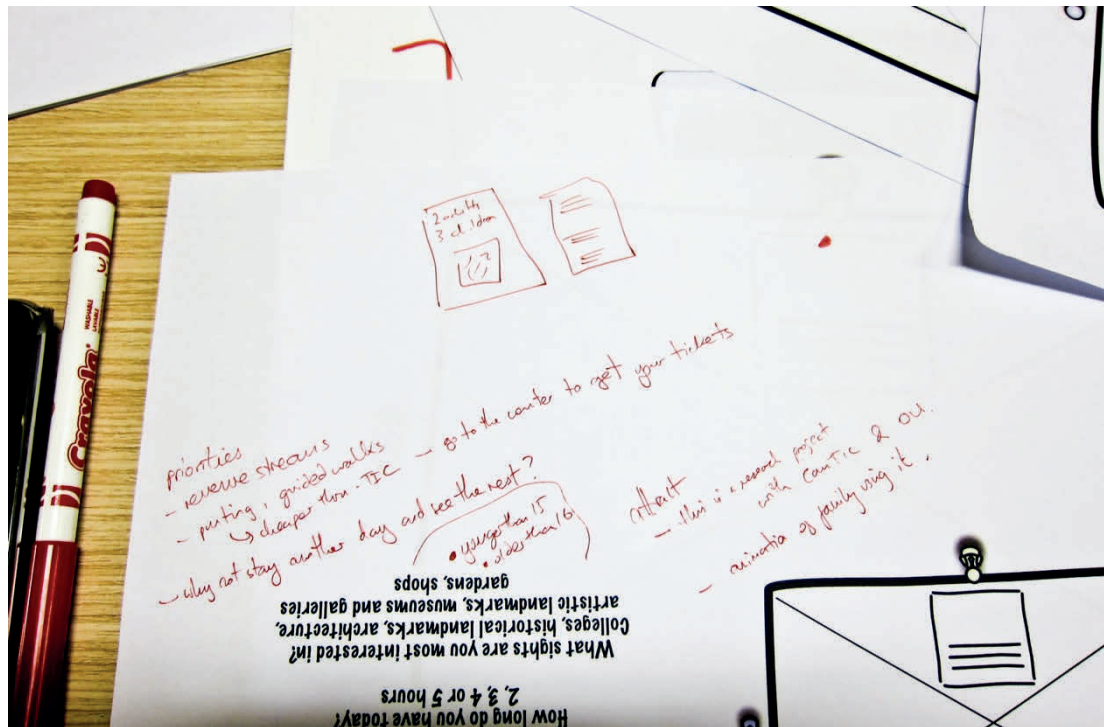


Figure 7.12: Notes are made of important goals for the VIC discussed such as revenue streams, promotion of ticket sales, prompting users to book a hotel and stay in Cambridge for another day.

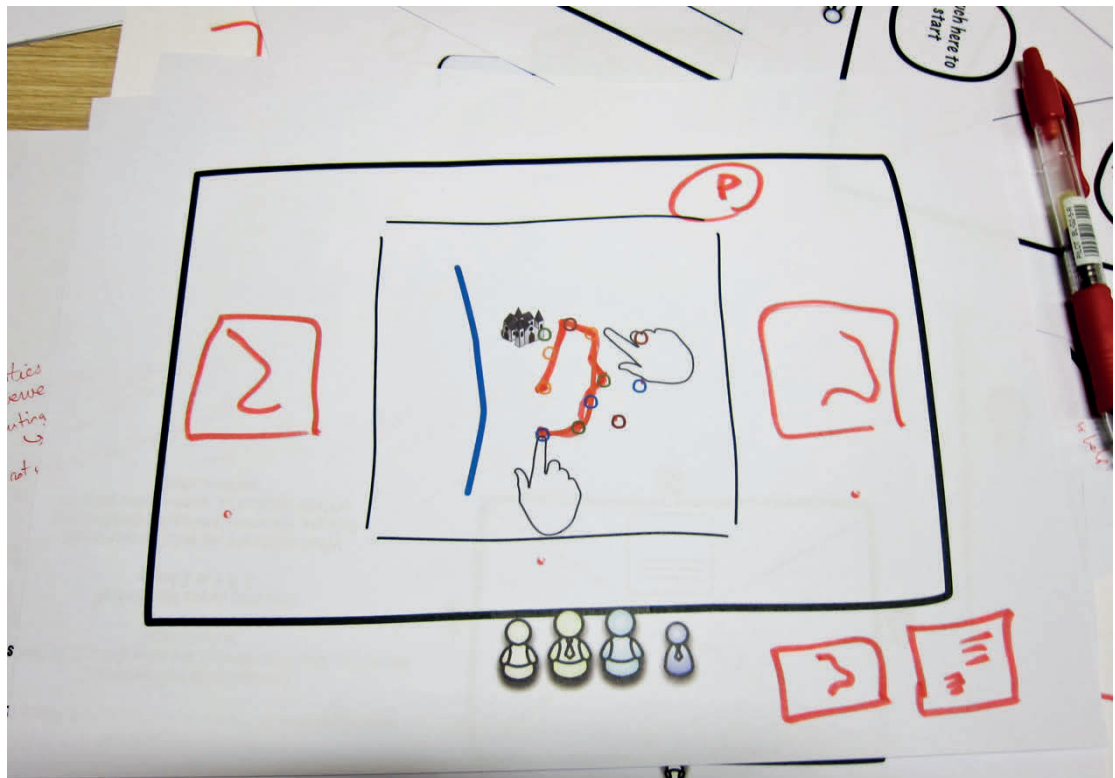


Figure 7.13: The annotated sketch is intended to show a possible interface design for the group/map stage of the interaction. Here users are able to define their own route by touching their chosen attractions in turn, or to select pre-calculated routes on the left or right. The print button is shown at the top (where it is less likely to be activated accidentally). The two boxes at the bottom show the printout, with a map page and a details page with text about the chosen attractions.

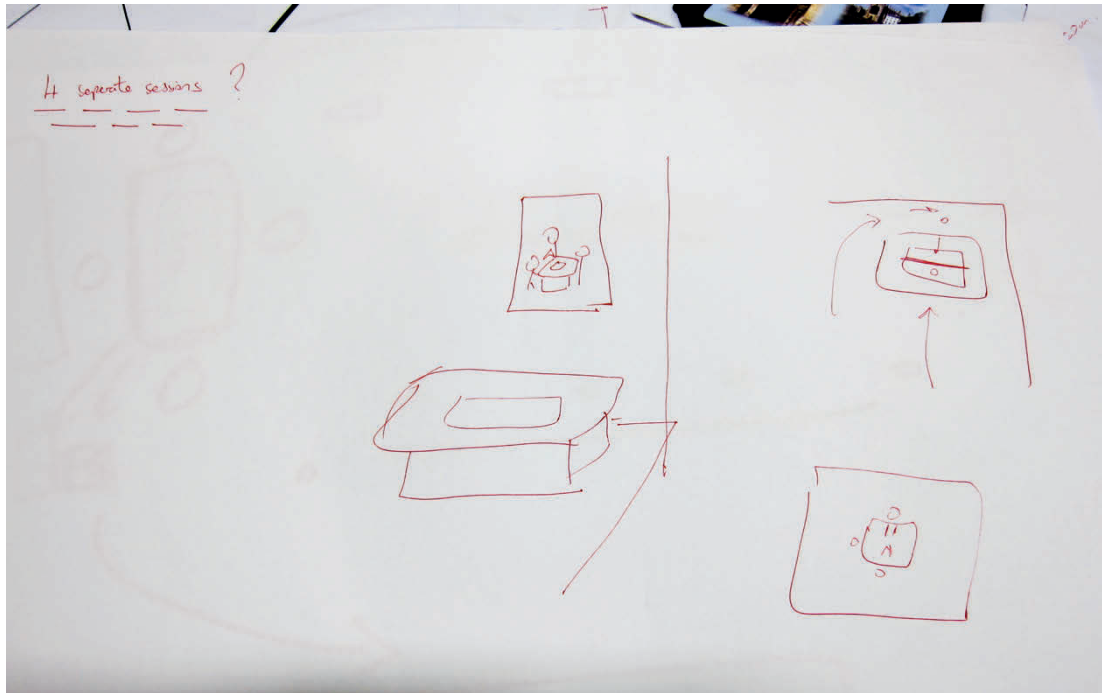


Figure 7.14: A sketch showing a poster next to the table, illustrating the envisioned use as a guide for novice users. Other markings show the exploration of how to manage multiple users concurrently.

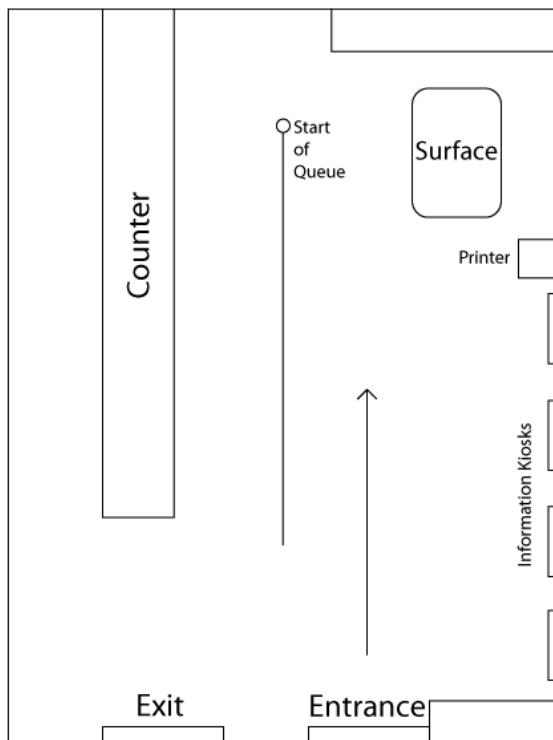


Figure 7.15: An overhead schematic of the VIC with the suggested position of the tabletop and printer.

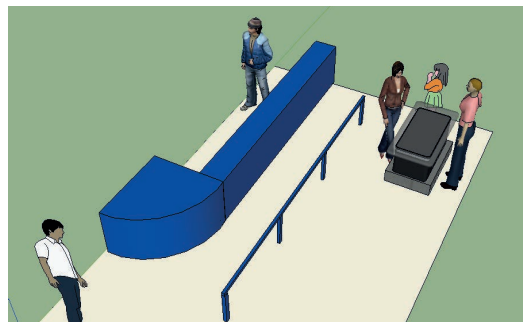


Figure 7.16: A visualization of placement of the tabletop presented to the VIC before deployment.

7.3.2 Design Workshop

Feeling that we had enough requirements gathered and a sensible idea of the context and potential user flow, a two-day workshop was carried out to brainstorm and refine interface designs. The workshop was attended by the author, Matt Davies of the user experience consultancy User-X, and Open University colleague Paul Marshall. Matt was able to provide experience from years of interface design and facilitating workshops in the industry. It was felt that an important factor for the success of the eventual design was for it to feel like a 'proper' piece of software, and not a laboratory prototype. Matt's input and graphic design skills were valuable in contributing towards this. Paul is a co-author on one of the principle papers resulting from this course of study and brought experience from studies with tabletop computers, as well as experience delivering large-scale HCI projects. As a project grows it requires consultation with experts in different fields (Hazlewood, 2010) to maximise the probability of success.

As one of the first steps, the goals of the stakeholders of the application were written down and placed on the wall on large pieces of paper. This aided in understanding how the distinct stakeholders in this project had separate but aligned outcomes desired for this project. Creating this external artefact was useful throughout the workshop as it was placed centrally in the room and was referred to several times as we evaluated concepts whilst prioritising which goals were most important and relevant to the overall success of the study.

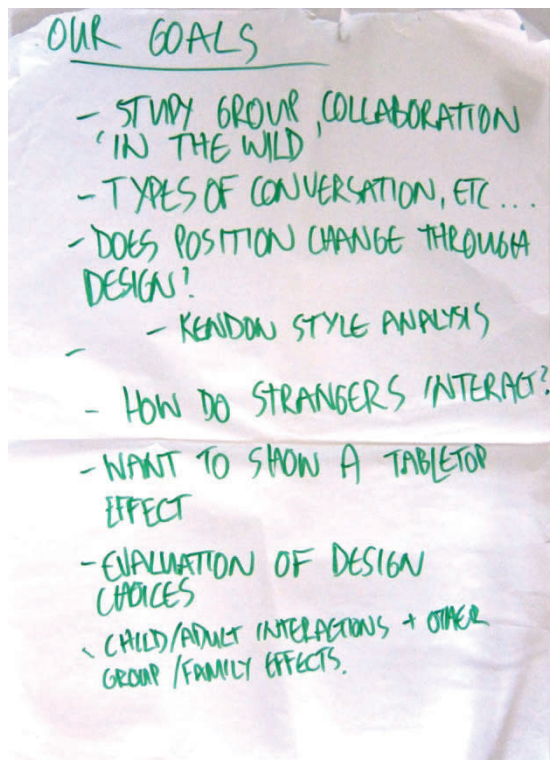


Figure 7.17: The research goals for the application are written on an A0 piece of paper and placed on the wall.

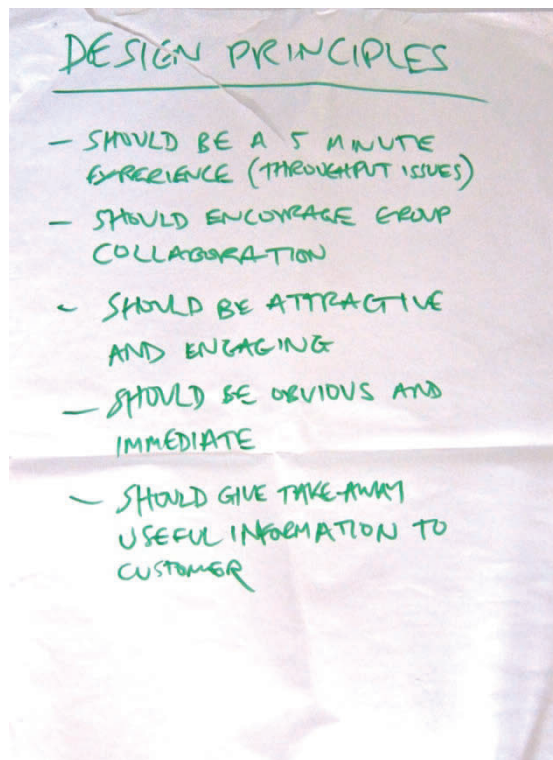


Figure 7.18: Some of the requirements are written down and placed on the wall.

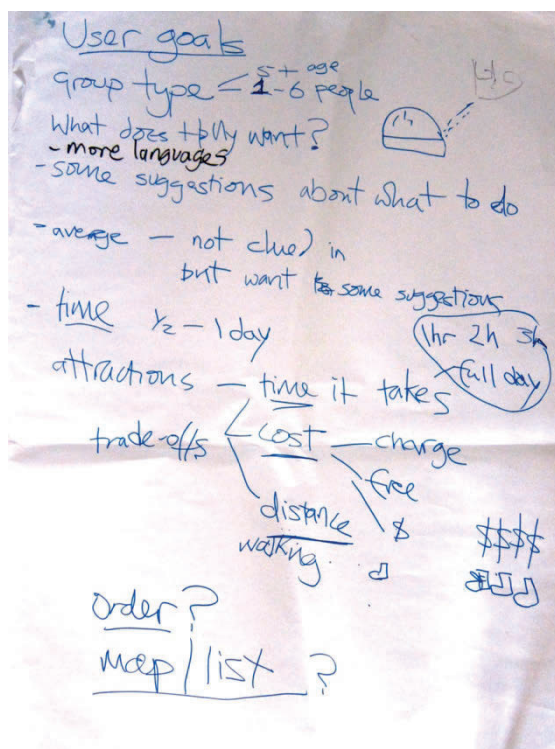


Figure 7.19: The user goals and some notes about different types of user are made and added to the wall.

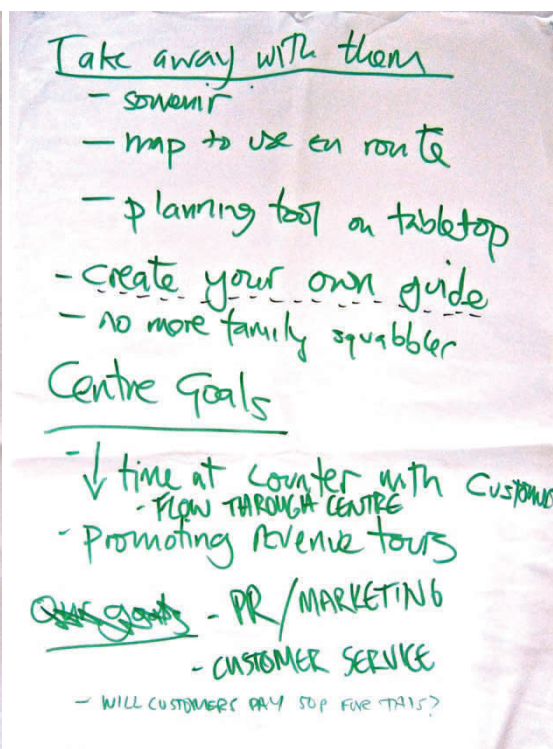


Figure 7.20: The VIC goals and the details of what artefact the users wish to leave with are noted and added to the wall.

7.3.2.1 User Profiles, Personas and Scenarios

To facilitate a user-centred design approach, a fictional family was presented to provide a realistic way to talk about potential users and ensure everyone present in the design team was thinking along the same lines. The choice of personas was influenced by the initial observations made at the Cambridge Visitor Information Centre. User personas are not intended to be literal descriptions of real people, but rather figurative representations of an average user or set of users which helps the designers of the application to be mindful that the needs, experience, assumptions, and other characteristics of the end users are different from their own.



Figure 7.21: A fictional family or tourists visiting the VIC, considered as a group.



Figure 7.22: The individual members of the group were also considered individually to highlight whether individual goals differed from the group's goals.

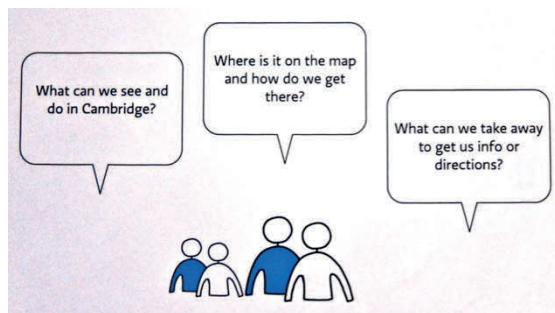


Figure 7.23: User goals are expressed as questions from the family/group.



Figure 7.24: A picture showing a group interacting with a tabletop was also used to help visualise the interaction happening.

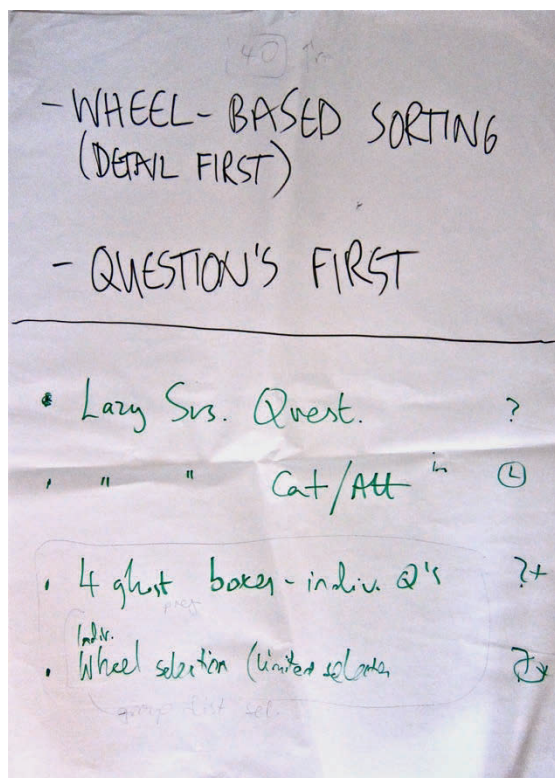


Figure 7.25: Several different interface directions are enumerated and compared.

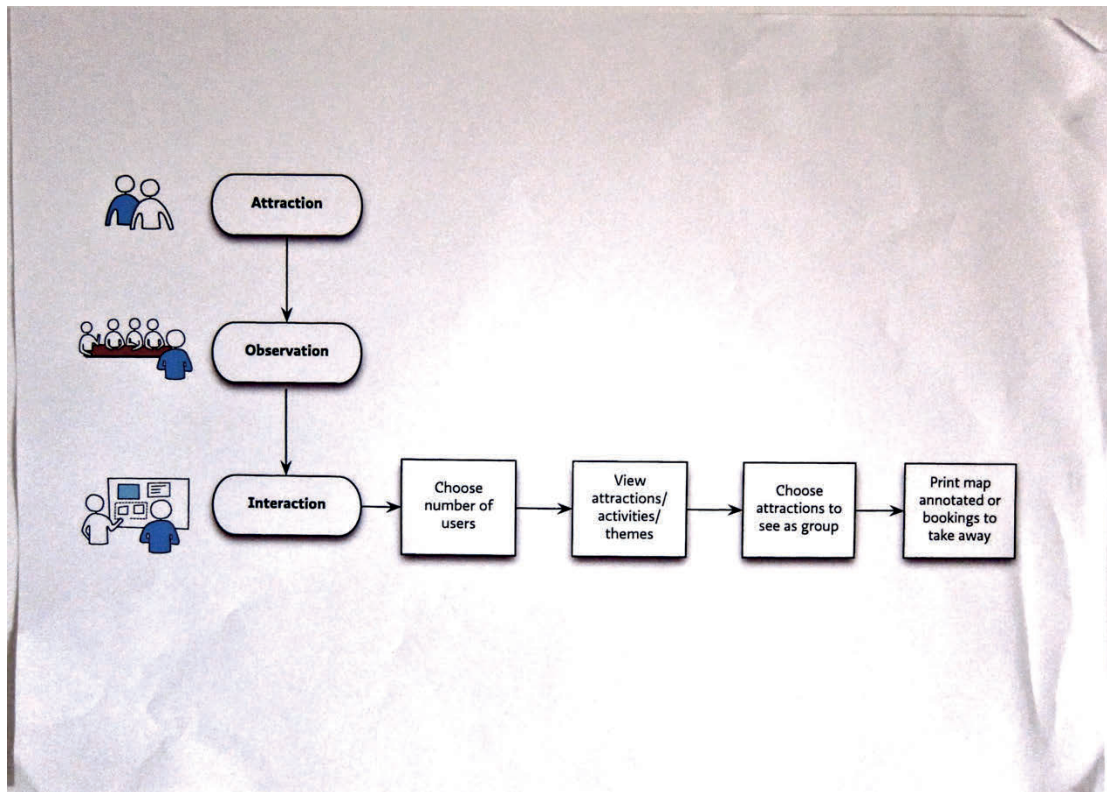


Figure 7.26: The user flow is broken down into several stages, crucially including the attraction and observation stages, noted as being important in the research by Brignull and Rogers (2003). The user flow was broken down into several logical stages where different categories of information were elicited from the user in different forms of collaborative grouping.

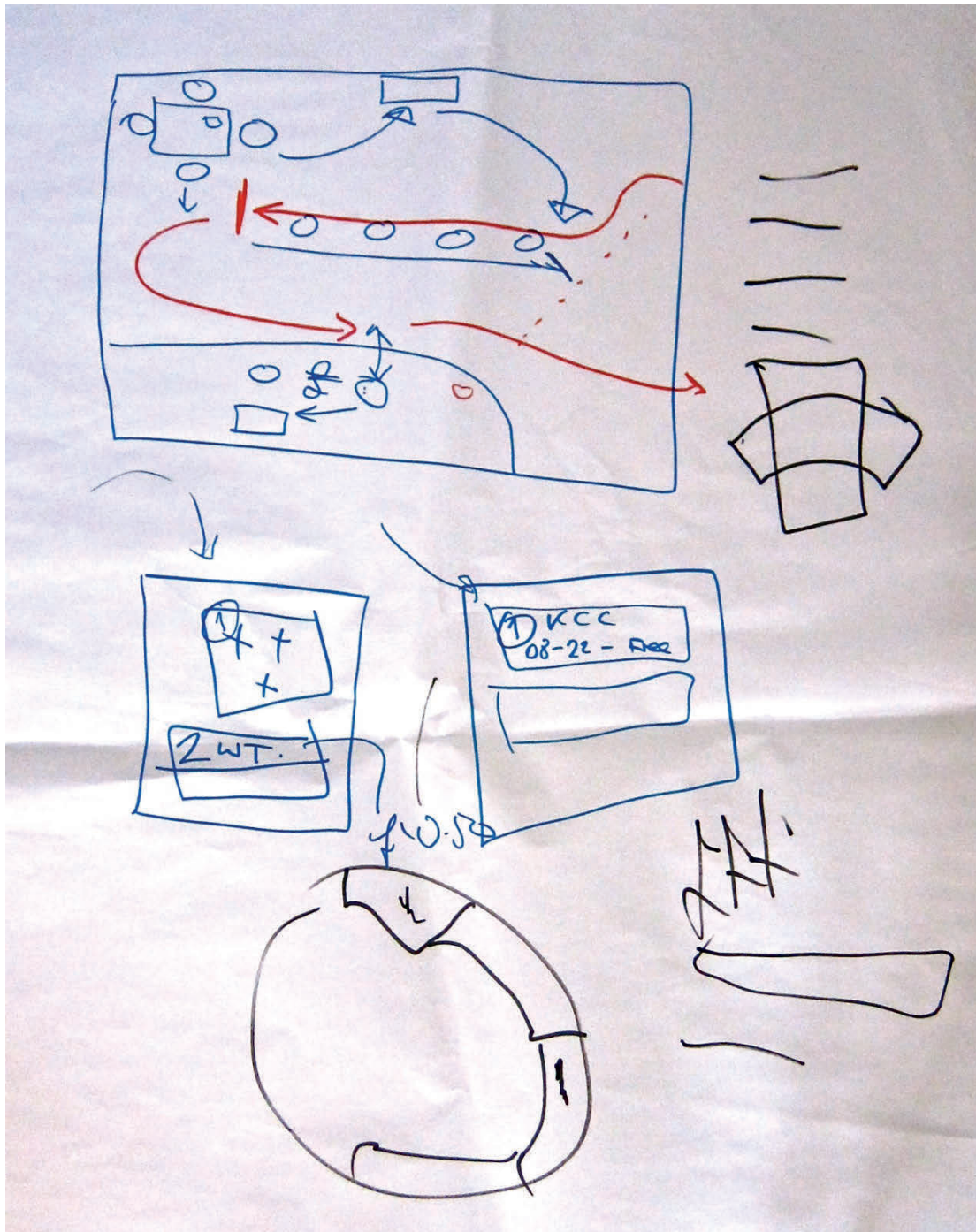


Figure 7.27: Various sketches were made to support the discussion of the user flow and how to meld the requirements into the overall application.

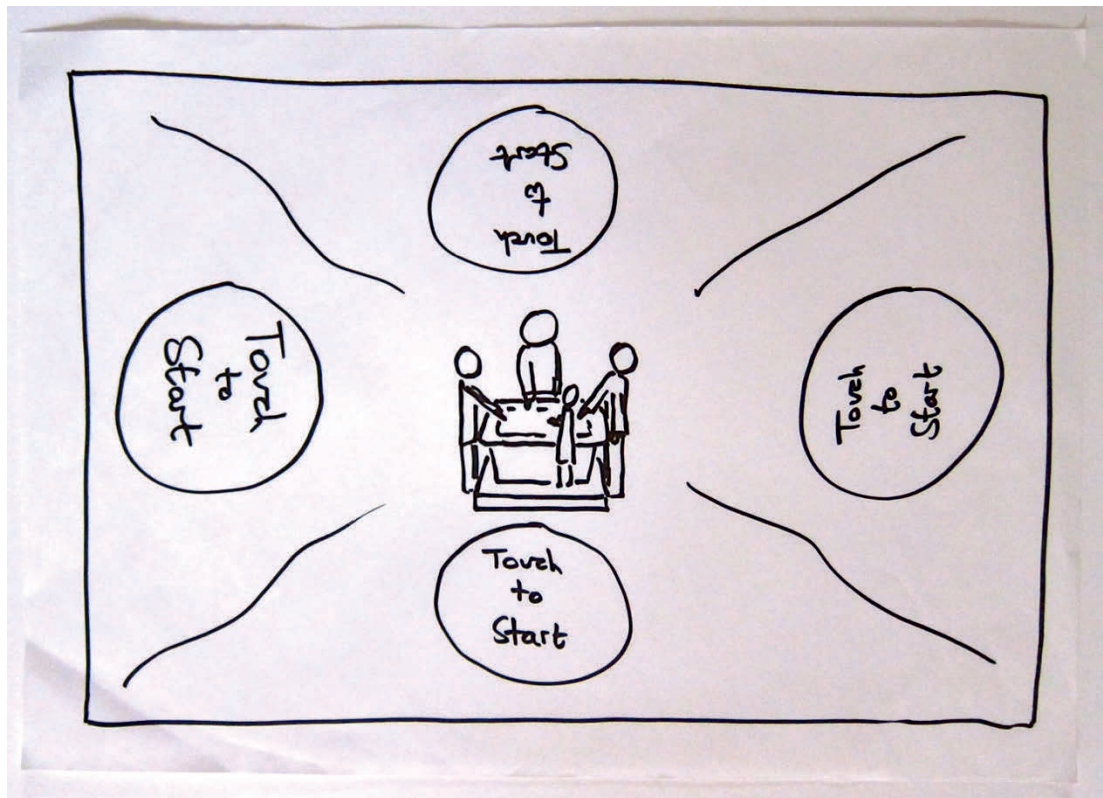


Figure 7.28: Rough drawings of the interface were made to allow for an interactive discussion about the different phases of the user flow.

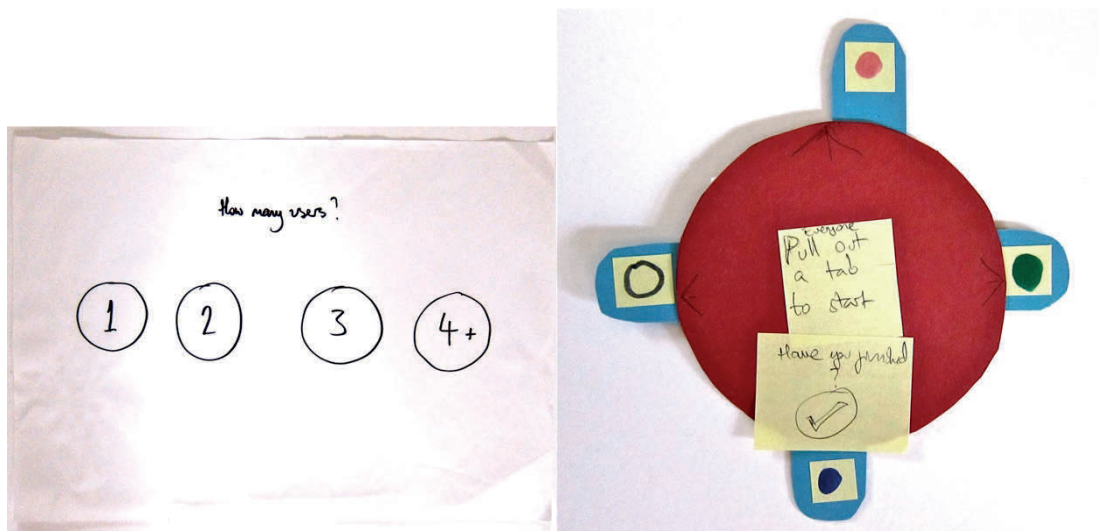


Figure 7.29: Here two concepts are considered for allowing different numbers of users to interact with the application. The method on the right was a new concept to allow users to join the interaction asynchronously, and ended up informing the paradigm used for the finished application, as opposed to the method on the left which required the number of users to be stated outright.

Initially, thoughts around how to design the interaction flow for the application relied on a coherent group approaching the tabletop simultaneously. Reflecting on this requirement revealed that this was unlikely to be the case. Observations of groups entering the VIC tended to reveal that individuals split up to forage for information. It was therefore likely that one person would reach the tabletop first. In order to prevent selection of the size of the group becoming a barrier to interacting, it was decided to design a solution which allowed for users to join asynchronously.

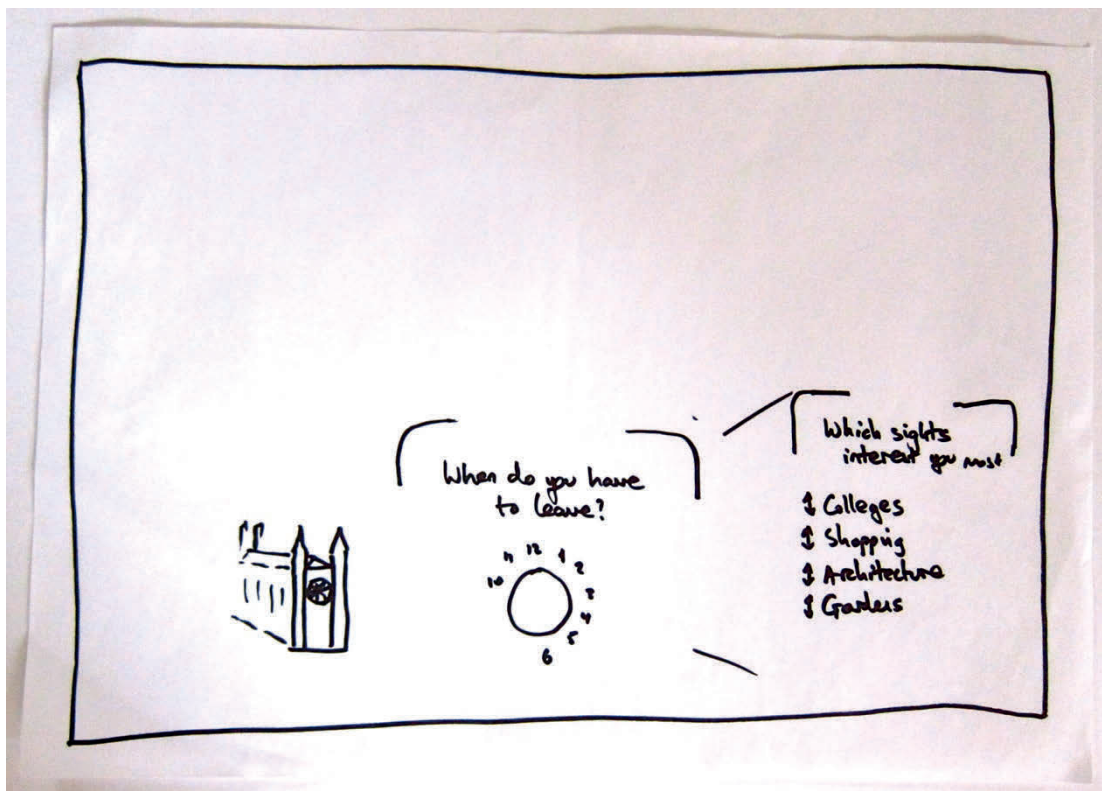


Figure 7.30: Several methods of organising the users exploration of the data set and eliciting their preferences were considered. In this figure a prototype is considered whereby the user selects their leaving time and prioritise their preferences for attractions to visit by categories.

During the design workshop, various interface metaphors and interactive flows were considered. We forced ourselves to work through alternatives which didn't seem natural in order to more fully explore the solution space. Various

dimensions were explored: the scope of the design (functionality and complexity), the logical order of the flow (specifying the size of the group up front vs. allowing users to enter asynchronously), the various factors of a day plan of the city (such as time available, subject areas).

The figure shows a paper prototype of a user flow for eliciting user preferences and constraints, consisting of six hand-drawn cards on blue paper.

- Card 1 (Top Left):** "What things are you most interested in? (select up to 3)". It features two columns of options, each with a checkbox. The first column includes "MUSEUMS", "GALLERIES", "COLLEGES", and "WALKS". The second column includes "ARCHITECTURE", "PHOTOGRAPHY", "SHOPPING", and "ACTIVITIES". A "NEXT" arrow points to the right.
- Card 2 (Top Right):** "How energetic do you feel?". It has three checkboxes. The top checkbox is labeled "BOUNCE WITH ENERGY" and the bottom checkbox is labeled "EXHAUSTED". A "NEXT" arrow points to the right.
- Card 3 (Middle Left):** "FAMOUS SIGHTS OR HIDDEN TREASURES". It has two checkboxes, both of which are checked.
- Card 4 (Middle Right):** "ARE YOU INTERESTED IN ~~CAMBRIDGE~~ HISTORIC CAMBRIDGE?". It has two checkboxes labeled "YES" and "NO", both of which are checked.
- Card 5 (Bottom Left):** "MONEY NO OBJECT OR DON'T MIND SPENDING A OR LITTLE. WATCHING THE PENNIES". It has three checkboxes, all of which are checked.
- Card 6 (Bottom Right):** "BRAVING THE ELEMENTS" and "STAYING INSIDE". Each has a checkbox, both of which are checked.

Figure 7.31: A paper prototype of the user flow for eliciting the users preferences and constraints is mocked up and evaluated alongside the alternatives.

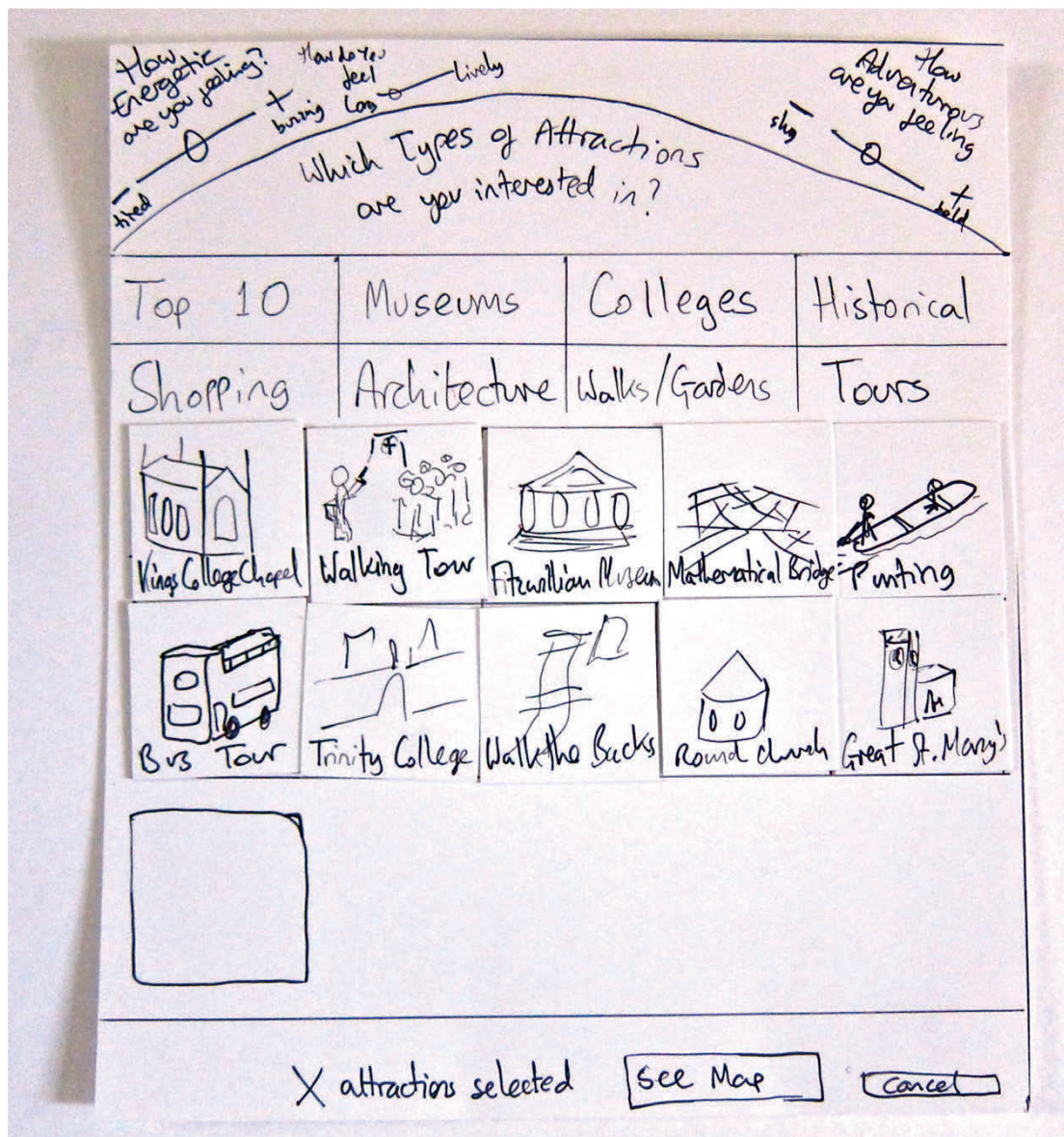


Figure 7.32: An experiment in combining two interface approaches. This solution was not popular with the group: it was felt it was over complicated. For a single-user web application, or perhaps even a mobile application it have been a viable solution, but for a multi-user system everybody interacting has to understand what is being discussed in the moment.

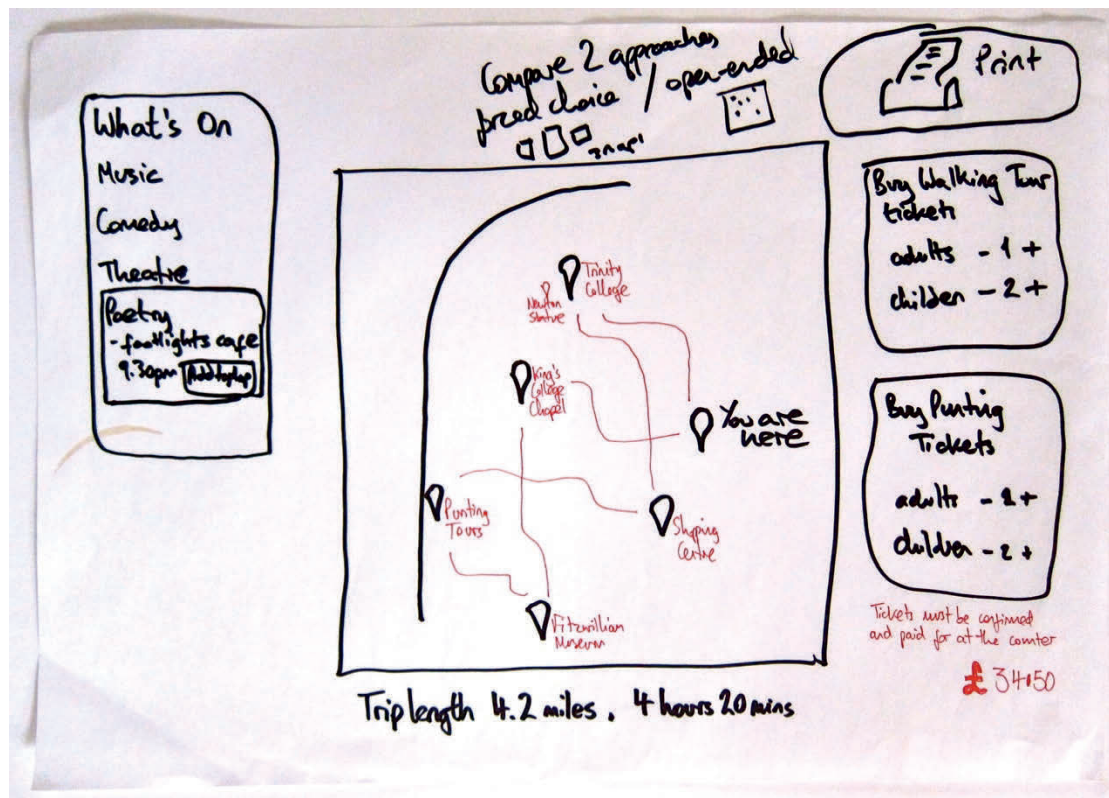


Figure 7.33: The interface for the group decision phase is considered. Here the addition of tickets for the tours is prominently featured. The 'what's on' section on the left is intended to extend the information from the wall boards, showing local events. Events of interest could be selected and added to the map, along with relevant venue and ticket information.

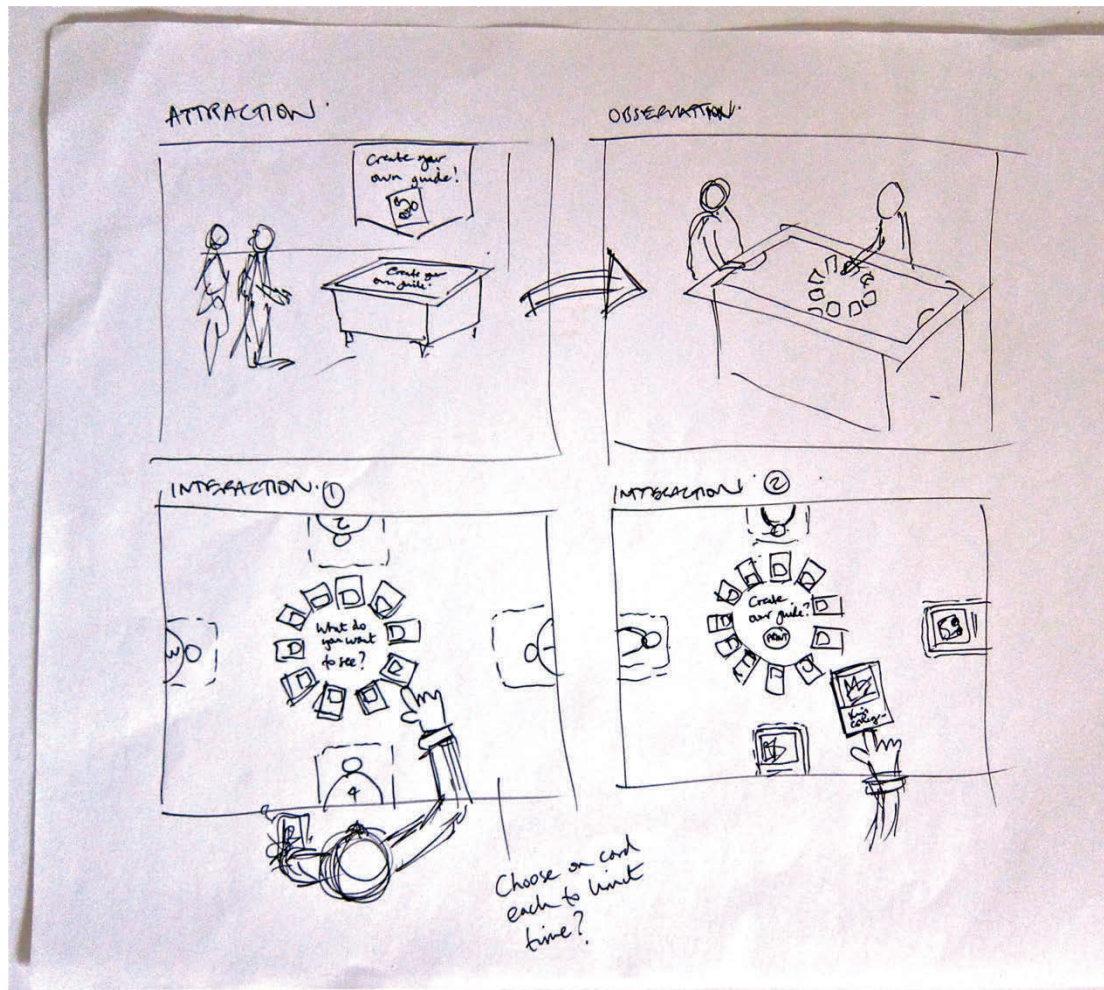


Figure 7.34: A 'Lazy-Susan' wheel with 'cards' representing the city's attractions was considered as a way of allowing casual interaction from walk-up users.







Figure 7.35: Various interaction metaphors were mocked-up with static 'comps' to see how they appeared in context.

The discovery of the Lazy-Susan metaphor led to the idea of the individual deck of cards metaphor.

7.3.3 Building the Requirements into the Interface

At this point we had evaluated several potential solutions in a divergent thinking fashion and it was necessary to now begin to converge on to a single solution. The presence of various design concepts resulted in tension with respect to how to integrate the good ideas from as many sources as possible.

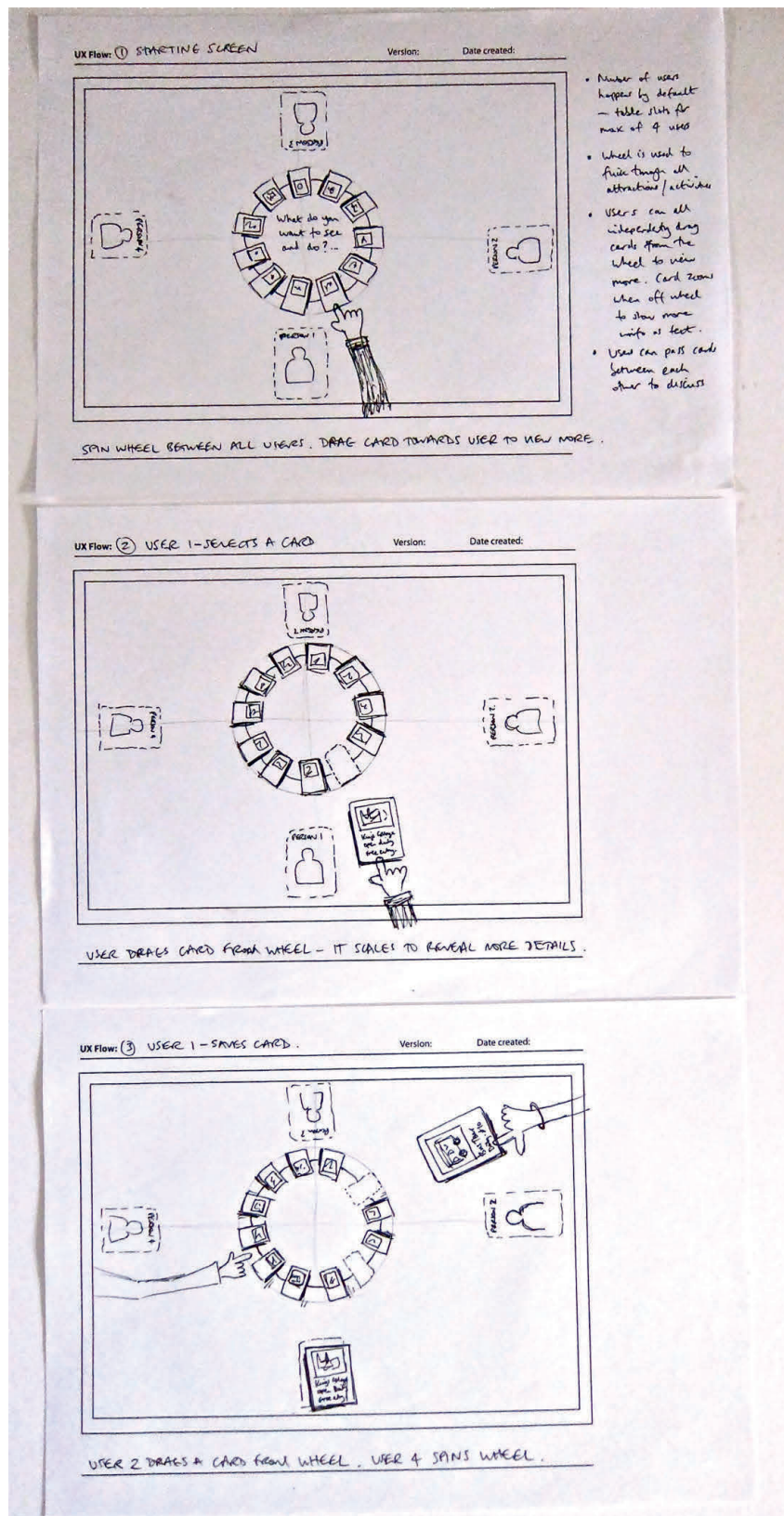
The various solutions and design metaphors were evaluated according to several factors deemed critical to the ultimate success of the application. For example, was a given solution likely to be easily understood by users of different ages, ethnicities, backgrounds and experience levels? Were the

interfaces able to support all of the necessary functionality required in order to complete a collaborative planning activity and produce a final end-product?

One factor which we were able to agree on was that reducing visual clutter was to the benefit of the system. This was in accordance with the recommendation of Guimbretière (2002), whose thesis discusses the difference in interface constraints between traditional desktop WIMP (Windows, Icons, Menus, Pointer) interfaces and touch-based interfaces. It was deemed preferable to have a wide and shallow information architecture as opposed to narrow and deep, which would require navigational menus. Similar to the solution chosen for the HealthTable application, simply presenting the interactive units of interest on the display for the user to sift through was thought to be the best interaction paradigm.

It was helpful at this point to imagine the actual flow the users would go through, helped by the personas. The mental models of the users were considered, and the importance of choosing an interaction metaphor which was unintimidating and naturally familiar was uncovered. As the group discussed this several 'motifs' emerged. The most important was the need to make the interaction ramp up in difficulty gradually, to entice and involve each user gradually, getting their involvement and motivation and 'buy-in' to increase. It was important to make each of the following steps obvious, and to keep the overall interaction as simple, playful and free-form as possible. It was felt that keeping the overall interaction time down to five minutes was important so as to prevent the tabletop becoming a blockage in the VIC.

Paper prototypes were employed at this stage to provide a means of performing a lean evaluation of the solution up to this point.



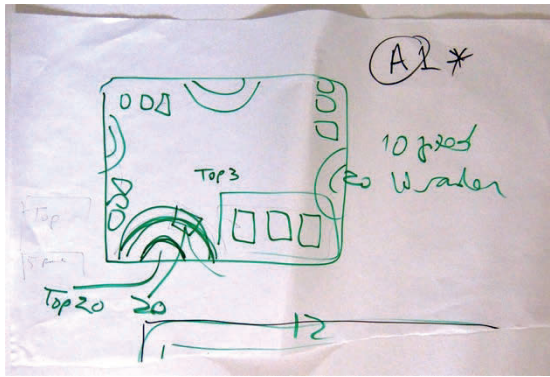


Figure 7.37: Another option for the exploration and selection of options is considered. This approach was the method finally selected for the application.

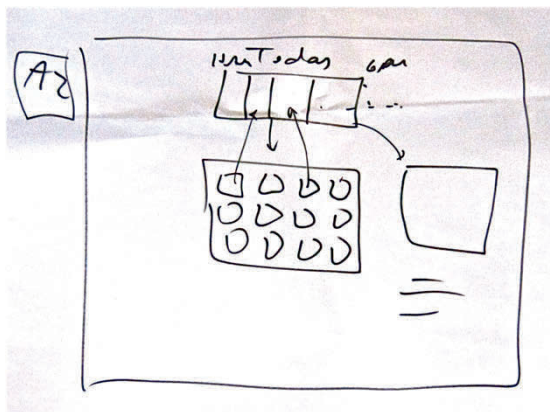


Figure 7.38: The group selection phase is considered, with the key functions of being able to refine the selection and order the chosen attraction highlighted.



Figure 7.40: Naïve users were brought in to test our paper prototype and to give feedback on the early designs.

Feedback from these test users uncovered that it would be important to allow the cards to represent more information easily. It was considered that the cards could be ‘flipped over’ to reveal more information and that the central area between the card decks could be used as a shared space for discussing individual attractions.



Figure 7.41: Using on-screen mockups to ensure the design worked on the projected screen.

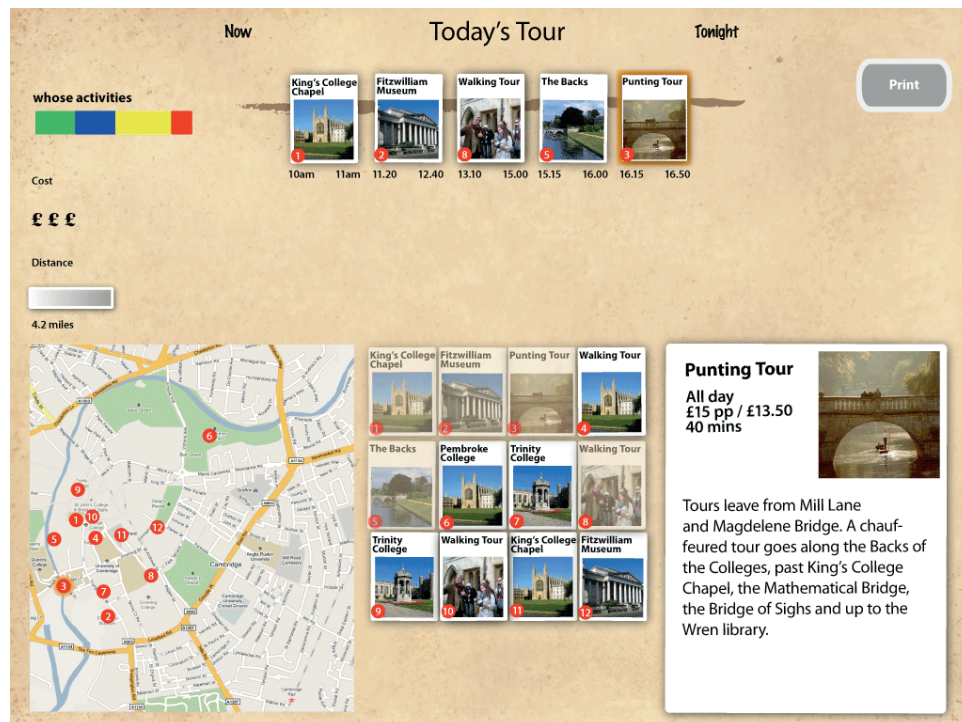


Figure 7.45: A high-fidelity mock-up representation of the group selection phase.

Static Photoshop representations ('comps') of the interface phases were mocked up in order to ensure that the various elements worked together graphically and text was legible at the resolution of the tabletop (1024x768).



Figure 7.46: The workshop room at the end of the second day.

7.3.3.1 Revised Mock-up and User Flow

At this point we had converged on a solution which used a deck of cards metaphor and had two stages: a free-form asynchronous exploration of the various attractions and selection of individuals' chosen favourites, followed by a collaborative refinement of the individual selections and production of the final group plan. The entire flow was thus four stages – attract, select, refine, print.

Icons were added to the cards to represent information such as disabled access and the cost of entry to that attraction. The creation of high-fidelity graphical resources for development of the design was carried out rapidly. Images from the web, visitcambridge.com and the Stride (a visitcambridge.com partner) website, along with text from the stride website and Wikipedia were used to produce the first pass of the attraction cards.

Producing 'good, short copy' for each attraction card was time consuming but crucial. Each card had space for about 20 words and had to express the key qualities of an attraction. The copy in particular went through several revisions in consultation with the VIC, and the space available developed as the graphical representations matured. It was possible to use longer descriptions on the group decision stage because of greater available on-screen space, and this was deemed important in order to allow the group to be able to make better-informed decisions.

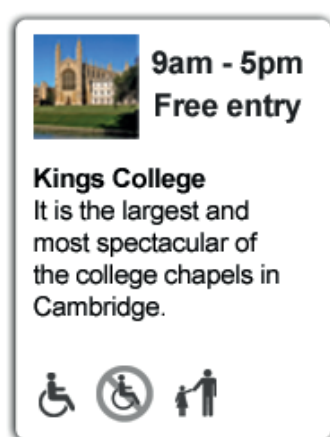




Figure 7.47: A Photoshop render of the multi-user stage, showing four users interacting separately. The yellow user has pulled out a card to read more information about a certain attraction. The green user is rotating the carousel to view the different attractions. The red and purple users are observing or reading.

The carousel metaphor was a useful interactive component. It allowed for adding more cards than would be possible physically by creating a virtual list of attractions that was quite large, but only a few were presented on screen at one time. When a card was pulled out from the carousel, a 'ghost card' was left in its place to maintain the integrity of the list.

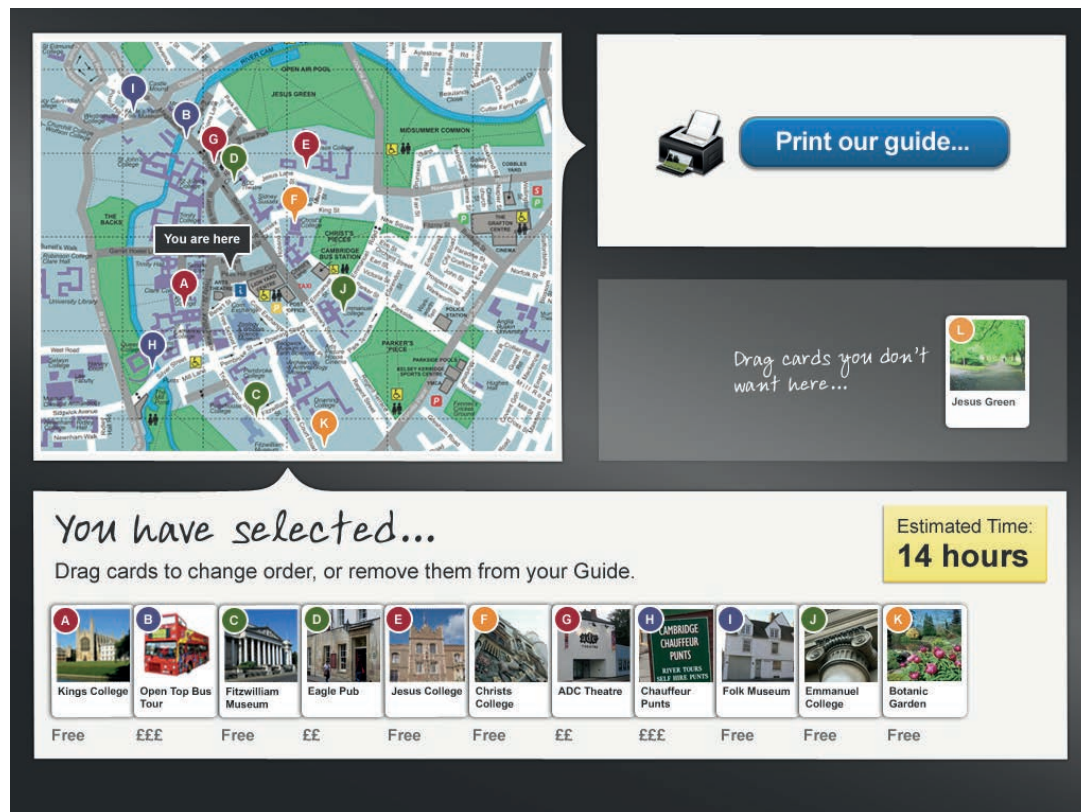


Figure 7.48: A Photoshop render of the group selection/map stage of the interaction. When a user touches one of the cards on the bottom strip, information about that attraction replaces the map. The map returns when the finger is lifted.

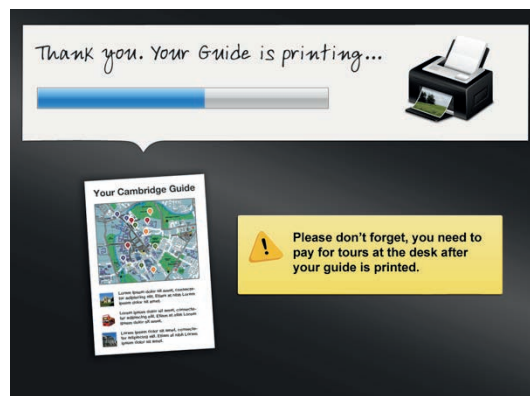


Figure 7.49: Whilst the map and information sheets are printing the user is shown a progress bar and reminded to pay for tickets at the counter.

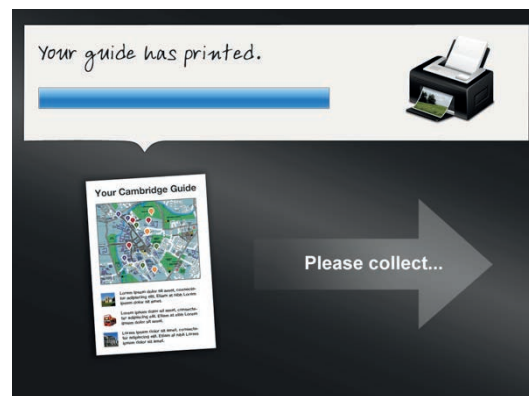


Figure 7.50: When printing is complete the user is directed to the printer located to the side of the tabletop.

The process of creating the high-fidelity mock-ups was important in resolving interface issues which were not apparent in the paper prototype stage, such as the readability of the text when rendered at an angle.

7.3.4 User Testing

After the initial design workshop, several days of intense development took place. I paired with an experienced programmer to help realise a working version of the application as quickly as possible in order to begin the first rounds of interactive user testing.



Figure 7.51: Designer (myself) and programmer (Stefan Kreitmayer) pairing on developing the application.

Two sessions of user testing with the prototype application were conducted.

The first had four naïve users and the second had three. The users were all from the university campus. Several issues with the prototype were revealed directly

through this session and analysis of the video recording of the sessions revealed several more.

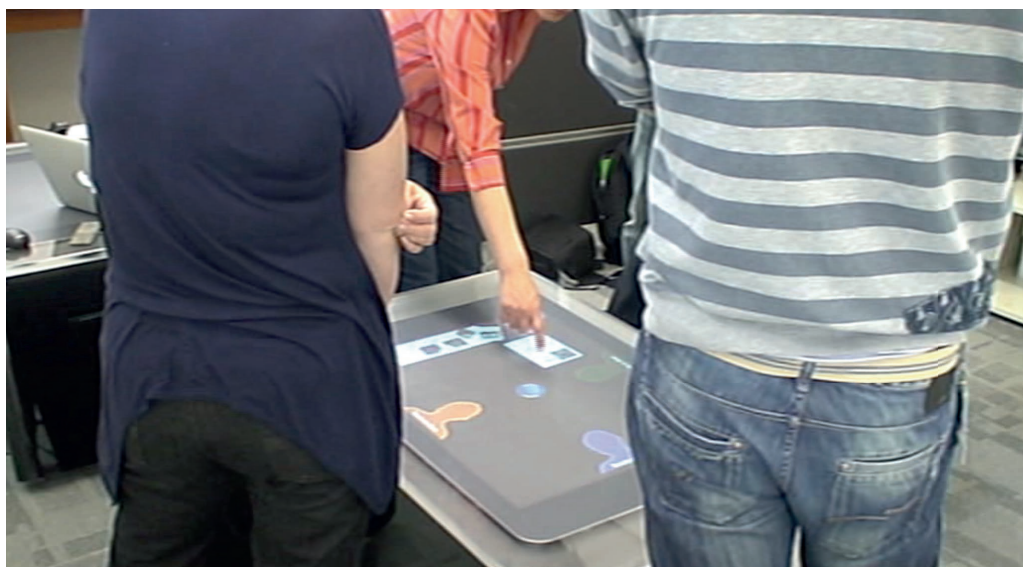
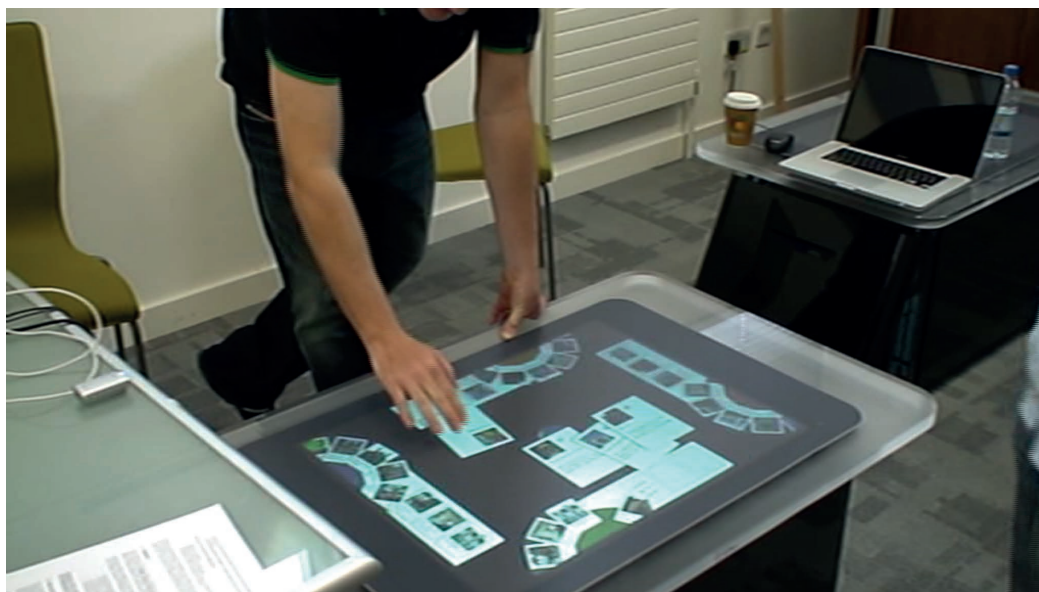




Figure 7.52: Stills captured from the video recorded in the user testing sessions.

Users were asked to interact with the prototype as though it were in the tourist centre. They were asked to act naturally and to employ a ‘think aloud’ protocol, whereby they externalised their thoughts and perceptions as they used the interface.

7.3.5 Contextual Help

A key finding from the user testing was that some users found it unclear as to how they were meant to interact with the tabletop. To assist them a video showing a ‘run-through’ of the interaction flow was displayed on the default ‘attract’ screen. This was intended to be viewed in its entirety to give at least one user of the interacting group an overview of the process and information about the interaction techniques required, or alternatively just to see part of it – enough to give the impression of the styles of interaction employed in the application, in a sense bootstrapping the interaction enough for the in-app contextual help to be enough to guide the user along. Additionally, contextual help was provided to scaffold the interaction in small stages. For example, in

order to reinforce the fact that the user should drag a card out of the deck to view more information, an arrow pointing outwards from the deck appeared a few seconds after that user first interacts with the deck with the words 'drag out a card'.

7.3.6 Printed Material

One of the key observations from the earlier observations of visitors to the centre was that a key artefact is a map, typically annotated in consultation with the information assistant, which the tourist took away with them for use as they navigate around the city. An example of the printout is included in Appendix 12.2.

This was chosen as the main representation for the printed material produced at the end of the session interacting with the tabletop. In addition, visitors were also free to take a printed description of the study and contact information from a pre-printed stack placed next to the printer.

7.4 Deploying the Application

It was agreed with the tourist centre that the table could initially be placed in the tourist centre for four weeks, although it was mutually decided to extend this deployment for a further two weeks. During the deployment, various small changes were made to the application in response to observations made of it in real use.

7.4.1 Signage

Before deployment, it was considered that signage would be important. Figure 7.53 shows the original poster that was used in the first days of the deployment. After initial observations, people were seen to have some misconceptions about the intended use of the tabletop. The revised poster exaggerated the 'group' feature and gave a visual cue for the intended use. The positioning of the signs was also important for

several reasons. Firstly, it was thought to be important that the users were at least aware of the sign as being related to the tabletop, so that they could refer to it for more information if they were unsure of either the purpose of intended mode of use of the application. Additionally, the placing of a stand with the sign provided a physical separation of the users interacting with the tabletop from the other visitors of the VIC.



Figure 7.53: A first version of the poster, which was deemed to be too cluttered.

The signage served several purposes: It advertised the presence of the tabletop from a distance and described the value and benefits of the application; and, it verbally and visually described the process at a high level, demonstrated how multiple users could interact simultaneously and that it was intended for a group of people. It also proved important in guiding the users' trajectory towards the table and away from the queue for the Information Assistant desk and marked a corner of the invisible boundary of use surrounding the table. Later on, during filming of the tabletop it was also a means of informing visitors to the centre of the purpose and nature of research being conducted and their right to opt out, and identified the researchers or the centre staff as being a contact to discuss any issues relating to this. This was in order to satisfy the ethical and privacy issues relating to carrying out video research in a public space.

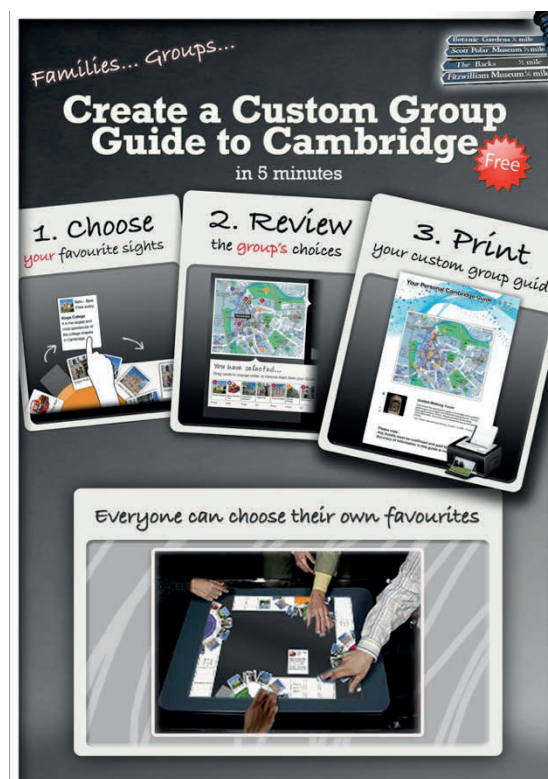


Figure 7.54: A second version of the poster showing how four people can use the tabletop simultaneously.

8 CamPlan: In-the-Wild Analysis and Evaluation

This chapter details the analysis of the observations, interviews and video recordings taken over the 32-day period of deployment in the tourist information tourist information visitor information centre.

8.1 Introduction



Figure 8.1: The tabletop is deployed in the VIC. It does not disturb the normal flow of business.

Taking the research goals, the goals of the VIC, and the overarching goal of supporting group planning in the tourist centre context, we evaluated the CamPlan deployment through observations, interviews, video analysis and feedback from the VIC. We were especially interested in how people approached the tabletop, how they came to understand the intended purpose of the

application and how to interact with it, how collaborative pairs and groups formed and how they transitioned as they moved through the application flow. We were also interested in the ways visitors reappropriated the table, used it in unexpected ways, and how it changed their visit to the VIC. We hoped that the tabletop would also be used by children and adults equally, perhaps allowing children to make more of an impact on the group plans. In relation to the broader themes of this course of research, we were interested in an overall evaluation of tabletops as a format for technological intervention in this setting, and what lessons could be learned in how to design successful systems for public and multi-user scenarios.

8.2 Observations

For the first 22 days of the deployment either one or two researchers were situated with the tabletop in the VIC making notes on the tabletop's usage. This included written descriptions and diagrams of users' movements around and near to the tabletop. Additionally, for the final ten days approximately 12.5 hours of video was taken, capturing 297 individual or linked sessions. The video was transcribed and analysed by two researchers and findings were compared.

As observations were made, the focus of the analysis was continuously refined, as well as improvements made to the application and signage. This allowed for focused analysis of various themes as they emerged from the initial observations.

The VIC had similar periods of busy-ness and calm as found during the initial period of research observations. Less people tended to use the tabletop towards the end of the day. On discussion with the IAs it emerged that people using the

VIC towards the end of the day were more likely to be looking to arrange accommodation, which might explain why the tabletop was used less.



Figure 8.2: A group of student from a nearby college come to investigate the table.

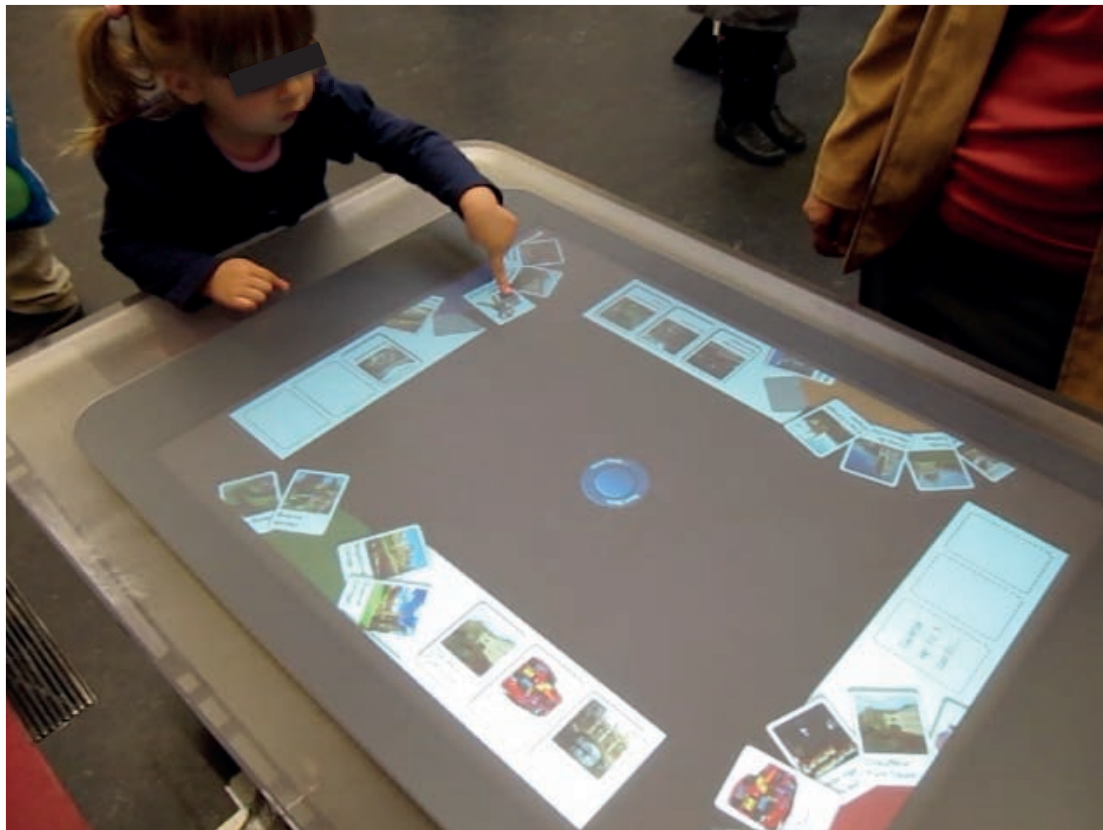


Figure 8.3: A young girl using the tabletop. The addition of the physical step at the sides of the tabletop stand allows her to see the screen and interact with one edge, but prevents access to other quadrants or the next step button. She had difficulty dragging items on screen without momentarily lifting her finger up, but enjoyed using the application. She was also familiar with the iPhone interface from her parents' phone.

Although the envisaged prototypical situation was for a family of four to use the application, this was not observed as frequently as initially expected. This calls into question the validity of the use of personas in the design process. In the development of the interface, a persona was employed to help us keep the intended user group in mind. This is a practice commonly employed in user-centred design in order to keep the development team focused on the needs of the ultimate end user and avoid the pitfalls of designing for their own needs. However, in this case, given the breadth of composition of groups who used the tabletop in the visitor centre, it is reasonable to question if a different approach to personas would have been useful.

Although it is impossible to predict all the different types of groups who could walk in to the visitor centre, it might have been helpful to create more persona groups to represent a wider variety of people and goals. This may have helped the team design for a more robust interface. However, it may have also made the process too complicated and stifled the rapid exploration of concepts which didn't immediately satisfy all the personas. On reflection, the use of the persona family was useful in our design stage, but for future designs, better validation of the chosen persona or personas could potentially elevate the overall success of the design.

8.3 Evaluations

In this analysis I use C1, C2, C3 and C4 as shorthand for the four 'carousel' positions on the table. In the VIC, C1 is closest to the counter, C2 is closest to the bench, C3 is closest to the wall and C4 is closest to the entrance (as shown in Figure 8.4).

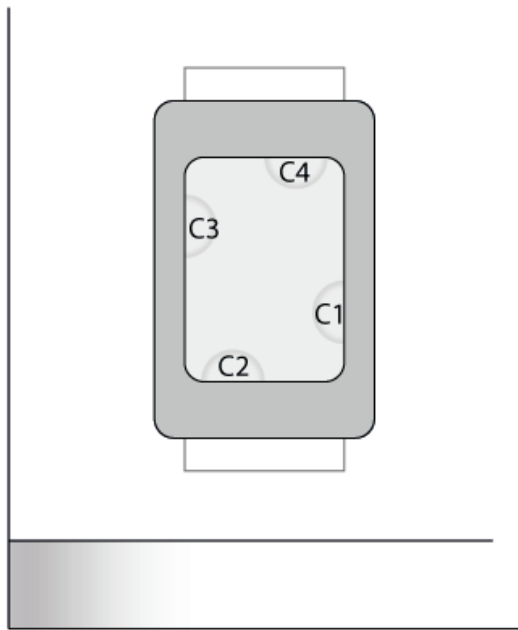


Figure 8.4: Diagram showing the C1-C4 notation used to identify positions around the table according to 'carousels'. C1 is the 'canonical' orientation and the orientation which matches the review screen.

8.3.1 Time-based and Log Analysis

We analysed logs of 1,626 sessions. This consisted of between 10 and 91 sessions per day with an average of 51 sessions per day. We found that 386 sessions resulted in printing (23.7%) and the average time from the first user engaging a carousel to printing was 103 seconds (with a standard deviation of 89 seconds). This beats our target of having the average session last no longer than five minutes.

The maximum time was 602 seconds, and the minimum was just 7 seconds. It is likely that the lower figure represents when a group went through the application flow several times and were adding cards quickly just to obtain printout. Some of the higher figures could represent sessions where one group of users abandoned their session and another group picked up the active session before the application automatically reset.

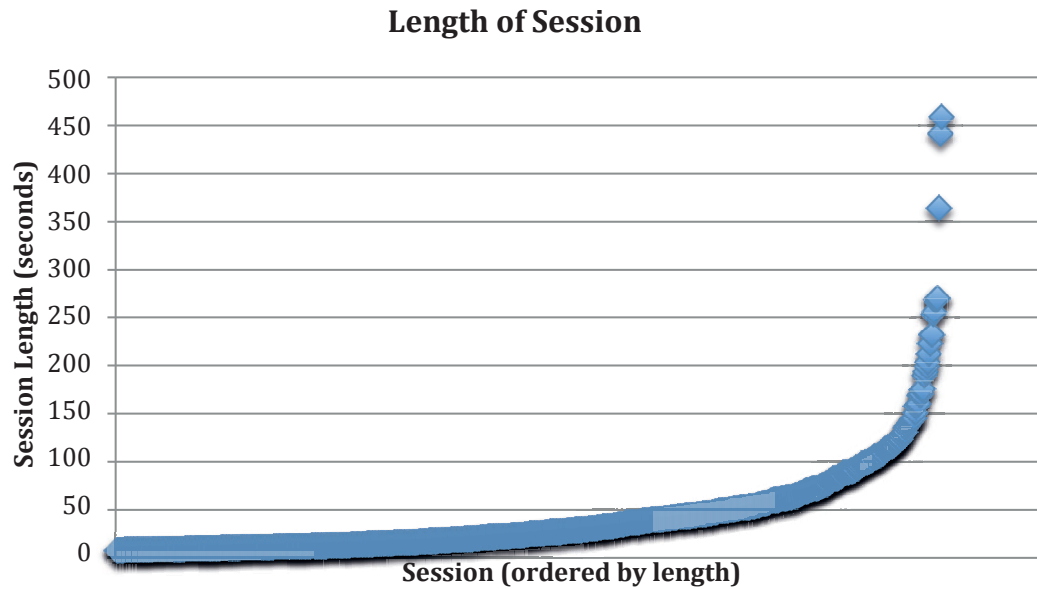


Figure 8.5: Session length in seconds.

The average number of users per session was 1.8 (standard deviation 1.0). The average number of cards viewed was 9, with the maximum number of cards being pulled out of the carousel being 196.

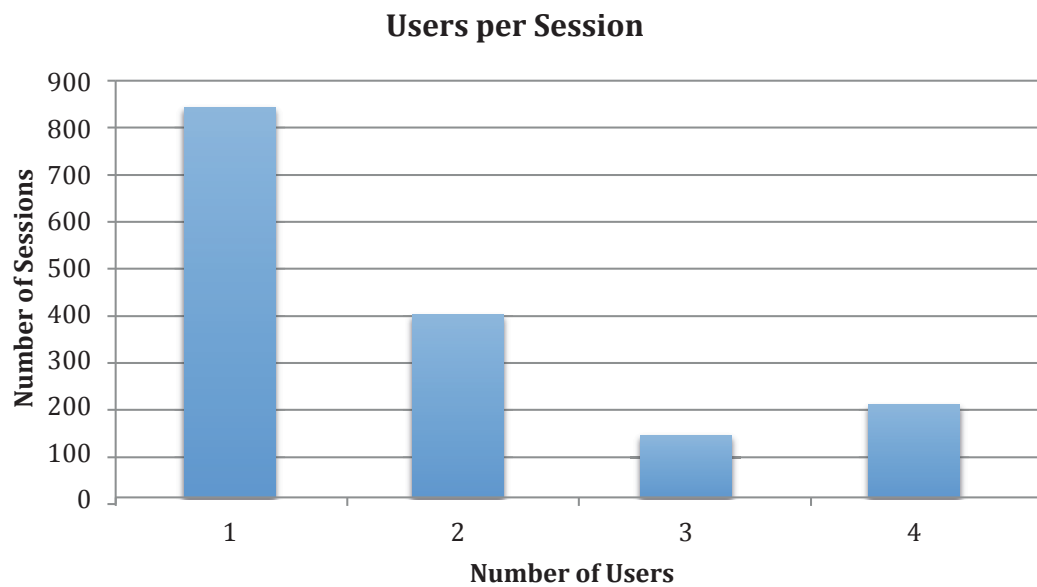


Figure 8.6: Chart showing number of users per session across the study.

Interestingly, 3 users was less common than 4. Without knowing the distribution of sizes of groups upon entering the VIC, it is hard to speculate why

this might be. However, the tendency to form pairs appeared to be quite strong. The greater number of 4's might simply reflect the fact that this category represents all groups with 4 or greater users, as several observed sessions consisted of larger groups.

8.4 Interviews

Several people were handed a printed questionnaire. The questionnaire was designed after several days of observation to assess which issues were pertinent.

The questionnaires were given to people after using the tabletop for completion and mailing back or emailing the researchers, however none were returned.

In-person interviews were carried out based on the questionnaire and responses were written down by the researcher.

Questions:

Users

- Are you familiar with and comfortable using touch-enabled devices (iPhone)?
- Have you used an interactive tabletop before?
- How long are you visiting Cambridge for?

Table

- Did you use the tabletop?
- Was it clear what the purpose of the application was?
- Did you enjoy using it?

- Was it clear how to use it?
- How could the application have been improved?
- Did this fulfil an important reason for you visiting the VIC?

Application Content

- Were there any attractions you were hoping to see but could not find in the application?

Interviews with some of these participants indicated that they were drawn to the tabletop simply because they were interested in the technology, or by the signage positioned nearby, and are summarized below:

1: Male, 40s

Found the application to be “completely intuitive.”

2: A group of three, consisting of a man, woman and child.

The man, who was using the application whilst the woman and child observed, states that it should be a bit more obvious that it’s for use by more than one person. This comment led to the changes in the representation used in the sign as mentioned in the section on signage in the discussion below.

3: A woman in her 30s

She walks up to the table following a half-completed session from a family who were using it just before. She interacts with the cards, reading a couple briefly. She then stops and goes over to browse the leaflets. I then asked her what she thought about the system. She said it was “fun” and “easy to use”, but it emerged

that she wanted more information and did not understand that there was a second step. “That’s why I went to the leaflets.” She did know that four people could use it and said it was similar to the iPod touch, which her children owned. Expanding on the point about it being easy to use she said, “Even I can use it.” She said that she was mainly looking for a walking tour to do to see the main attractions in the city centre. She had used the kiosks and thought the tabletop had the same information but said that she thought the tabletop interface was better.

4: Australian couple in their 40s

This couple, who were travelling around the UK, said that they had “no idea what there is to do in Cambridge.” They had both used the tabletop in C1, sharing the interactions. They said that they “didn’t know it was multi-user” and that they thought it was “like the PCs (kiosks).” They also said that they found it “user-friendly... better than the kiosks.” However, they also stated a wish to see more information about each attraction in the first stage.

8.4.1 Video Analysis

Video was captured in the final 10 days of the deployment and clips of the tabletop in use were selected for detailed analysis.

8.4.1.1 Coding

In order to structure the video analysis we followed the technique used by Peltonen *et al.* (2008) in dividing the usage in sessions. In effect this meant that periods of continuous use were marked as a session, with new sessions being marked when a period of more than 20 seconds elapsed without usage or

engagement of the users in the immediate vicinity of the tabletop. Accidental interactions, such as through people placing down maps or brochures, without using the tabletop directly, were not counted as sessions if the person or group did not go on to use the tabletop later.

8.4.1.2 Number of Users

The video captured covered 297 sessions. The length of sessions varied greatly from several seconds to over 10 minutes and the mean session length was 2 minutes 10 seconds. These sessions covered individuals and groups of differing sizes. 158 sessions involved single users, 92 involved pairs of users (184 people) and 47 sessions involved groups of three or more people (183 people). These figures represent the number of people who used the tabletop directly. If people who were seen to be part of the interacting group were included in the numbers the totals would be 121 individuals, 204 people in pairs (102 sessions) and 284 people in groups (74 sessions, mean groups size 3.8). Thus, while the tabletop obviously enabled individual use, the dominant pattern of interaction was with other people.

These figures show that individual use was well supported by the application, but group use was the dominant mode. As may be expected, the ratio of active users to passive users decreases as the group size increases. This may reflect a natural limit either on the part of interface, i.e. how many people can physically interact simultaneously, or as a factor of social operation, i.e. how many people can operate simultaneously whilst still having an effective group activity.

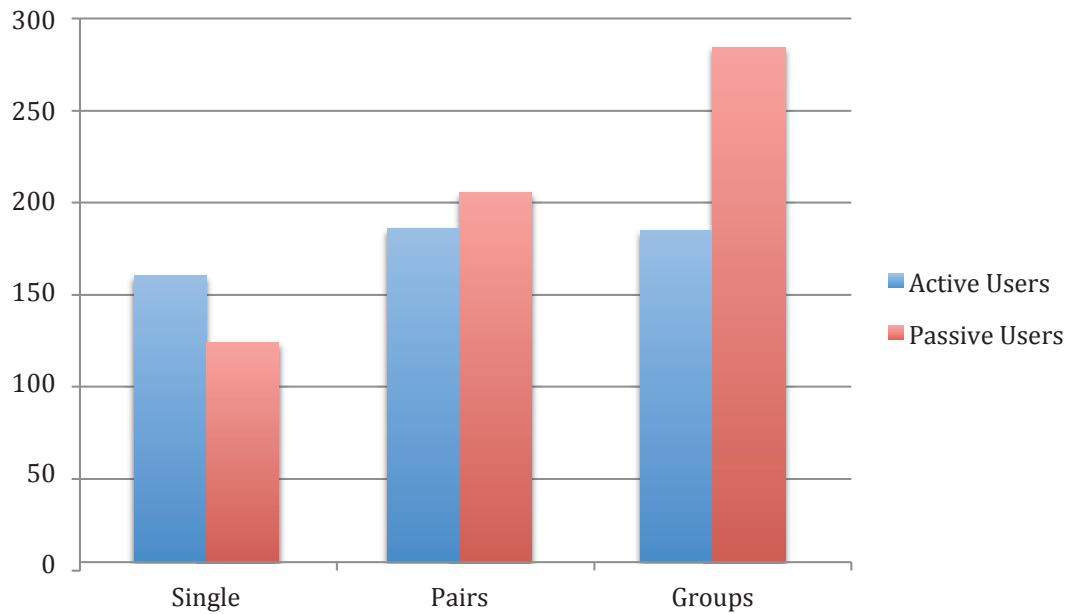


Table 8.1: Number of active and passive users, by group size per session

The following section provides a series of vignettes intended to give an illustration of how the tabletop was used by various individuals and groups. Following that is a series of sections describing certain themes which were extracted from the transcriptions of the video and the system of observations and notes made by the researchers.

8.5 Vignettes

The following vignettes are included to give an impression of the raw experience as it happened.

8.5.1.1 Vignette 1

12.15pm 15/5/10 - From handwritten notes

A group of three people walk up to the table. They appear to be a family consisting of a father (1), mother (2) and son in his 20s (3). (1) and (3) use C1 and C4, respectively, whilst (2) observes from a position between them. (3) gets

to grips with the system more quickly than (1). (1) keeps reading and selecting cards. (3), who is waiting for (1), starts playing with cards, dragging them out from the carousel and flicking them about. When (1) has chosen three cards (3) presses the next step button, but he has accidentally invoked a session on C3. Not realising that the prompt there needs to be confirmed as well they tap at various point on the table in confusion. They leave the tabletop. The mother does not interact with the tabletop or contribute any dialogue.

DESIGN CHANGE

Having observed the difficulty with the accidental session a change was made to the system to stop a dialog box appearing for accidental sessions, which are defined as sessions where no cards are selected by dragging into the boxes.

8.5.1.2 Vignette 2

13.20 15/5/10 - From Notes

A group of three men in their 20s enter the centre. Two of them (1) and (2) walk over to the table and start using C1 and C4. They both get to grips with the system immediately. At one point (1) adopts a two-finger touch style and inadvertently grabs two cards out of the carousel. He then drags them both over to the boxes and drops one whilst bringing the other back to the carousel with the thumb of his other hand.

After making their selections they go to the review screen and reorient to the canonical orientation (C1). They look at the map briefly and then restart and return to their original positions. They then both make three selections, choosing some cards the same and some different. It appears as though they

have taken the first session to be a 'learning trial' and the second session as a 'proper go'.

They go to the review screen and reorient themselves again. (2) comments on the time required (6.5 hours), then drags out a card. Their colleague (3) comes over from the brochure racks and joins them. (1) talks with (3) and (2) takes over, driving the interaction with the table. They all then discuss whether to print, then decide to do so.

8.5.1.3 Vignette 3

10.45 28/5/10 - From Notes

A family consisting of father (1), mother (2), and two young boys (3) and (4) enter the centre. (3) and (4) go straight to using the table, in positions C2 and C4. "Look at this," says (3) to (2), who is close by looking at the brochure racks. The mother comes over and the child says what he has done with the table. The mother explains what the purpose of the table is "for making a plan." The kids have selected three cards and then look for other things to do. They enjoy dropping cards on each other's carousels repeatedly and watching the shaking head animation (a wiggling animation added to the cards when it returns to the originator's carousel). One says "no, no, no, no" shaking his head like the card.

(3) says to mother, "I think we should go to King's College Chapel."

"It's free" adds (4), incorrectly, or possibly talking about another card. "I want this to win," he shows a card to the mother and other child. "I've chosen these two," says (3) to (4).

The father comes over and watches briefly before saying “look, it says here...” and reaches over to grab the Zoology Museum card from C4. Mother and father then read the card together. The mother and father then step back from the table. Father says “let’s go”, and they all leave.

8.5.1.4 Vignette 4

12.00 28/5/10 - From Notes

A pair of users walk up and start using the system as a pair using C1, quickly selecting three cards and going to the review screen. They study the map briefly then say, “start again: let’s do this more seriously.” They restart and discuss their selections on the first screen more carefully: “If we see these things on the (walking) tour we don’t really need to go in then.”

“Let’s see how long this takes,” says the other and they go to the review screen.

“2 and a half hours... do we just print?” asks one, and the other presses print.

I interviewed these users and discover that although they saw the silhouettes they did not realise that they could use separate session individually. They were in Cambridge for one day. They stated that they found the tabletop “better than leaflets.”

8.6 Themes

People generally were very comfortable using the tabletop, understanding the touch nature of it. There were no examples of people simply watching the tabletop as a video without trying to interact with it, other than people looking at the table and deciding not to use it.

8.6.1 Approaching the Table

People typically approach the table when they see it after walking in. This may be after some time spent walking around and looking at objects closer to the entrance such as the kiosks, the brochures and the posters.

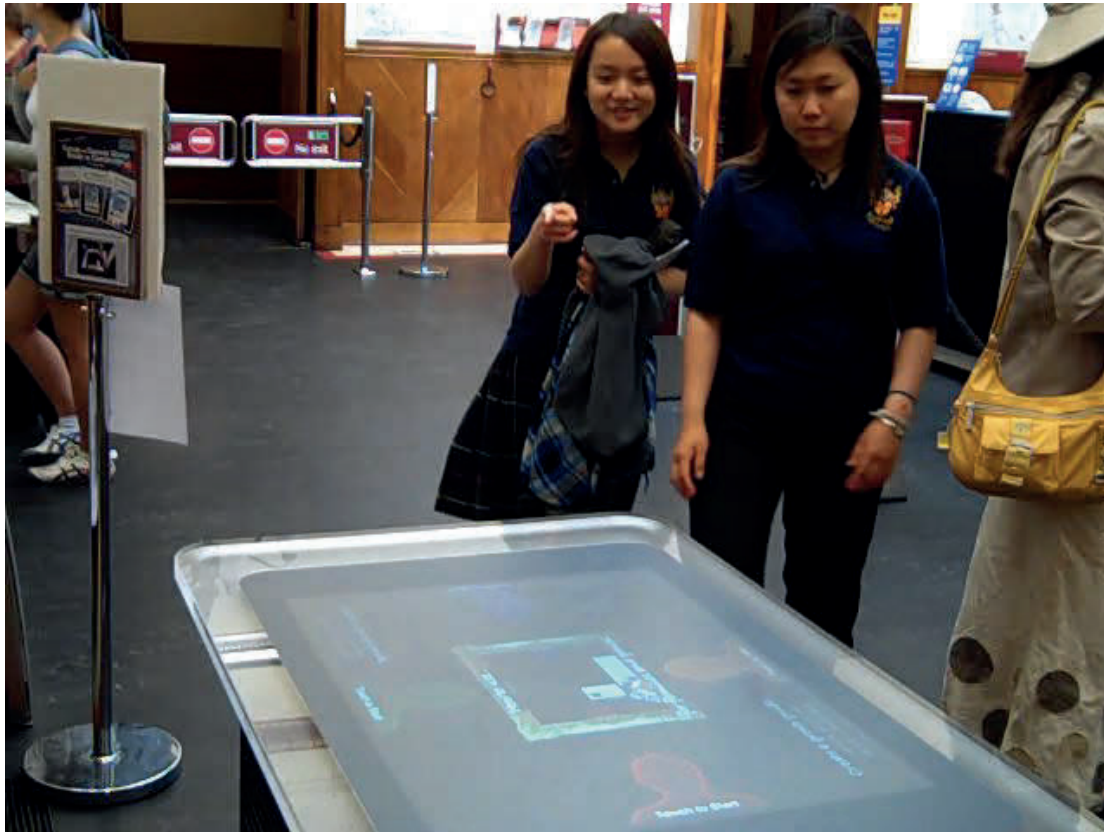


Figure 8.7: A typical approach.



Figure 8.8: A father and daughter approach the table.



Figure 8.9: A group of four children use the tabletop simultaneously.

Leaving the table – typically, when people leave the table, they go either to leave the centre or to go to the counter.

Staggered arrival – groups often split up before they reach that side of the room.

Honey pot effect – observers gain interest and confidence by watching others – this works well when the centre is medium-busy. This was concordant with findings of Brignull & Rogers (2003) who found that a certain number of people were needed to maintain a high rate of use of a device in order to continually attract new users.

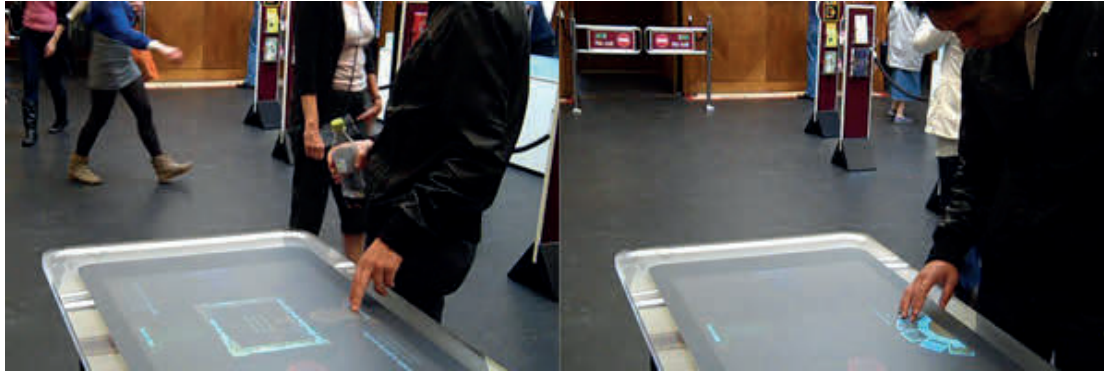


Figure 8.10: A man arrives at the table with a non-committed stance as indicated by his perpendicular orientation and use on non-dominant hand. Afterwards he switches to his dominant hand, moving the water bottle he was carrying and aligns his body parallel to the tabletop, indicating a higher level of commitment to the interaction.

Act of nonchalance – hovering around threshold of interaction – if he fails at interaction less embarrassment, as he has not indicated a commitment physically.



Figure 8.11: The man's partner arrives from the counter and initially observes from the normal position. She then starts to interact, taking over from him, and he withdraws his hand to afford her better access.

User substitution – when a user joins somebody who is already using the tabletop, sometime they take over that person's session, rather than starting their own. It could be that they have not considered the possibility of starting their own session, and are more interested in sharing one session, particularly as a pair.

8.6.1.1 *Indirect Observers*

The honey pot effect, as discussed by Brignull and Rogers (2003), was observed in the deployment of CamPlan. Visitors to the VIC observe the tabletop in use by people who are not connected to them, observing their interactions and waiting for the tabletop to become free, leading them to use the tabletop after the current session is complete.



Figure 8.12: A woman looks on as a pair use the tabletop.



Figure 8.13: A woman reads the poster for more information after observing a group using the tabletop and printing out a map.



Figure 8.14: A young woman observes from a position behind C4, after browsing the brochure racks. She starts interacting when the current user leaves.



Figure 8.15: Two young women, who were using C2 and C3, become demonstrators for a group of children and their mother who congregate around the C1/C4 end of the table. The children only observe and do not use the tabletop themselves.

8.6.2 Understanding Value

Some people studied the poster before using. Some even studied the poster after using, as if to check what the real purpose of the tabletop is supposed to be after playing for a while.

8.6.3 Failures to Engage

Observing users engaging with the application for the first time underlined the importance of success of first touch. If the user did not get a satisfactory response to their first interaction with the system they were much more likely to abandon it straight away. Whether it was because the touch did not register, or perhaps they didn't observe the reaction they expected, in the context of a

visitor to the VIC who is weighing up the various information sources around them, they might assume that the technology is broken, or simply not worth the effort of repeatedly trying to learn how it works.

There was some evidence of “default satisficing behaviour,”⁶ where users would double tap the screen: if people don't rapidly get the hang of a new interaction, or if it requires extensive effort, then they are liable to revert to previous learned behaviours and persist with those, especially if such behaviour produces results. Given the importance of building the users' confidence and their trust in the application, we made a change to support this gesture.

Brignull & Rogers (2003) posit that with public technologies there are several important thresholds. Firstly, the threshold of awareness, whereby the potential user must become aware of the technology and its relation to their immediate goals. Once that threshold is reached, they must then pass the threshold of interaction. Their hesitancy to interact may stem from not knowing how to interact with a new system, or perhaps concerns about feeling foolish if seen failing to use it in front of others.

Several people were observed eyeing the tabletop hesitantly, and, although there is no way of knowing what they were thinking, some off-hand viewings were turned into interaction and others were not. If the visitor only becomes aware of the tabletop whilst already in the queue, they may feel that the time

⁶ The term “default satisficing behaviour” was used by Prof. James Fleck in personal communication to describe this type of behaviour which is a ‘default’ based on experience with other technologies.

invested in queuing would be wasted if they leave the queue to interact with the application. If there is no queue, they may decide to go straight to the counter to interact with the IAs. Some people played non-committedly with the application whilst waiting at the threshold of the counter, but left when it was their turn to see the IAs.

When the centre was very busy, it was not easy to see the tabletop from the entrance and many people joined the back of the queue close to the entrance, perhaps knowing that the VIC has assistants, but not about the tabletop, and therefore make an assessment quickly.

8.6.4 Atomic Groups

When a group enters the VIC a common observation was that they would split up into information foraging roles, typically with at least one person queuing for the IAs and one browsing the brochures.

One user, who was a middle-aged woman, used the tabletop whilst waiting in the queue. She was in the queue with her partner/husband, who remained in the queue. She selects one card (the Round Church), goes to the next step, studies the map for about ten seconds, then prints out. She looks around for the printer, but gets called over to the counter as her husband is called forward. Then she walks over to the counter, seemingly divided between collecting the printout, which is currently printing, and joining the activity at the counter. She joins the counter and they ask a few short questions, which takes about one minute. She then goes back over to the printer, collects the printout and makes a donation.

11.45 28/5/10 - From Notes

A group of four people, consisting of three women and one man, all in their 40s. The three women gathered around C1, with two of them close together (1) and (2), jointly driving the interaction, and the third (3) slightly to the right, observing. After using it for a while, the man reaches between them and taps on C4. One of the women says “oh, maybe we can use them separate.” (2), who was close to C4 moves around and starts using it, whilst the man and woman observers position themselves between C1 and C4. (1) and (2) both choose three cards each, but they do not go to the next step. The whole group leaves.



Figure 8.16: A man taps his partner on the back to get her to turn around after having proceeded to the review screen. This indicated his wish for her input in this stage of the application flow.

If a visitor interacts with the table and finds it of value, they were sometimes observed leaving to recruit their group-mates and bring them back to the table to show it to them.

8.6.5 Demonstrating (Show and Tell)

The demonstration of appropriate actions was seen in many social settings. In the figure below, a young boy who has been playing with the table for some time tries to help a young man (not related to the boy) who has been staring at the carousel for some seconds. The boy drags a card to the selection boxes without being prompted to do so, but out of an eagerness to help the young man use the application.



Figure 8.17: A child, who was previously using the tabletop, leans across and puts the card in the box for a user who was hesitating. This unsolicited assistance was seen a few times. The ability to help with a short gesture is less socially awkward in some cases than expressing verbally and was more likely to be used by younger people.

Younger users were more likely to use a physical action to show how to use the system compared to older users who were more likely to use verbal guidance.

Also, the more close-knit a group seemed to be the more verbal interaction would be observed. People who were less familiar with each other tended to talk less, but would still make physical instructions such as pointing and gesturing in order to help other members, whether of their group or external.

As in the example with the young boy in the figure above, there was often a sense of pride, or a gentle form of showing off which accompanied a gesture of physical instruction.

In many cases users tried to explain the use of the application to each other. This included peer-to-peer, adult to child and child to adult.

Children were also commonly seen to be keen to show their achievement to adults. For example, after reaching the review screen, bringing their parents' attention to the map and explaining their choices.

"What do you do?... oh yes"

Parents scaffolded their children verbally and physically. Typically they would help their children physically if they were having difficulty using the tabletop by either grabbing their hand and using it to move the card or using their own hand to move the card for them. Typically, they were more likely to physically scaffold younger children, and to verbally scaffold older children.



Figure 8.18: A father physically scaffolds his daughter by grabbing her hand and dragging a card out for her using her finger.

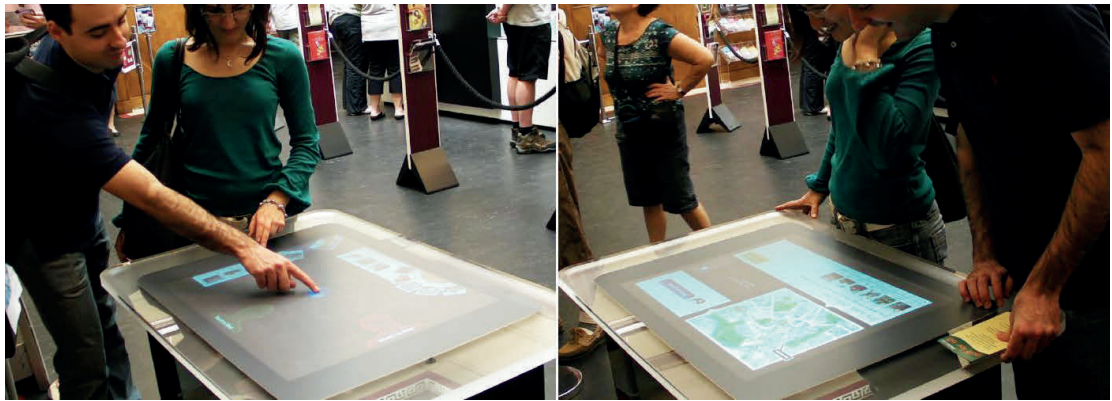


Figure 8.19: Man reaches across to press next step button after woman has selected three cards. They then reorient to the canonical position on the review screen.

People in groups of two or more were more likely to read out text and instructions aloud than users who were alone. This served several purposes. It gave an indication to others of where they were in the application flow, it helped other users to understand the system and keep up with each other and it served to get people's attention if a certain action was required.

If a user ran into trouble, another user would commonly first tell them what to do, giving them hints. This would happen either whilst they continued to use the system themselves or they would stop and give their whole attention to bringing the other user up to speed. If the other user continued to have trouble the more advanced user may move their cards for them.

Users would also discuss their strategy and meta-planning for using the application. For example, "let's go back to that one: where was it?"

14.05 14/5/10 - From Notes

A father (1) walks up and starts using the tabletop in position C4. After a few seconds he steps back to the mother and two children (2), (3) (aged approximately six and three).

(1) "You can play together, look" [he points at the tabletop, then drags a card around the screen] "There, get it?"

[The two children come up next to the tabletop]

(1) "You press the red person, look, now pick the ones that look interesting" [he says to (3). (2) is using C4 and (1) moves around to C2 to help (3)]

(1) "Drag it into the white folder, look" [(1) grabs (3)'s hand and uses it to drag a card from C2 into the boxes. He gives verbal instructions to (2)]

The mother (4), who was picking up leaflets, walks over and joins the father, standing in front of C1.

(4) "This is good, isn't it? Do you want to play?"

[The mother starts using C1 and the dad observes from in between C1 and C4. They make selections and go to the review screen. The mother is studying the screen. (2) presses 'start again' and (4) quickly presses no.]

(4) "I've found a free art collection... look, that tells us all about it... this is really good, isn't it?"

[(4) presses print and collects (3) and (2) and they move towards the printer. She collects the printout and is now keeping (3) and (2) close to her side]

(4) "It's 50p"

(1) "Yeah, I can do that" [the father then donates 50p.

[They leave the centre together]

16.10 14/5/10 - From Notes

An elderly couple walk over the tabletop. After watching the video on the attract screen for about 15 seconds the man (1) starts using C4 and the woman (2) starts using C3. They have slight problems with dexterity when it comes to rotating the cards, but are able to use the system effectively. They discuss their experience as they learn to use the system:

(2) "Do you have to put them in here?" (referring to putting the cards in the selection boxes)

(1) "I don't know. I'm just trying to see" [(1) adds a card to the boxes then points over to the boxes of C3. (2) then drags a card across. They each have made three selections and look around the screen for what to do next.]

(1) "Ah, next step" [they both press yes but appear confused for a while as (2) has accidentally started a session at C2. He then taps yes on the last confirmation dialogue and they go to the review screen. They both reorient to the C1 position, study the review screen for a few seconds without touching anything else and press print.]

12.25 31/5/10 - From Notes

A young girl plays with the tabletop for a few moments whilst her parents are looking at the wall boards. She brings both her parents over to show the tabletop to them. "Isn't that good," says the mother. "What about this one?" she

says, dragging out a card from the carousel. The girl quickly grabs the card and puts it into the box. The parents seem to get satisfaction out of seeing their child learn and become proficient with the system.

8.6.6 Learning As You Go

Sometimes users would go around the application flow several times, learning how to use the application. For example, a user might go through the select and review screens. Sensing that this completes the application flow, by giving a summary, a map and the option to print, they restart and make different selections, comparing to the previous session. When they were confident in using the system they might call to other group members and demonstrate to them.

“Okay, let’s do this properly” said one pair who explored the application flow once then went back and restarted.

Most commonly seen when 2 or people were using the tabletop, the “do-over” is when a group iterate over the application, making improvements in strategy, or changing the focus or theme of their attraction selections as they proceed.

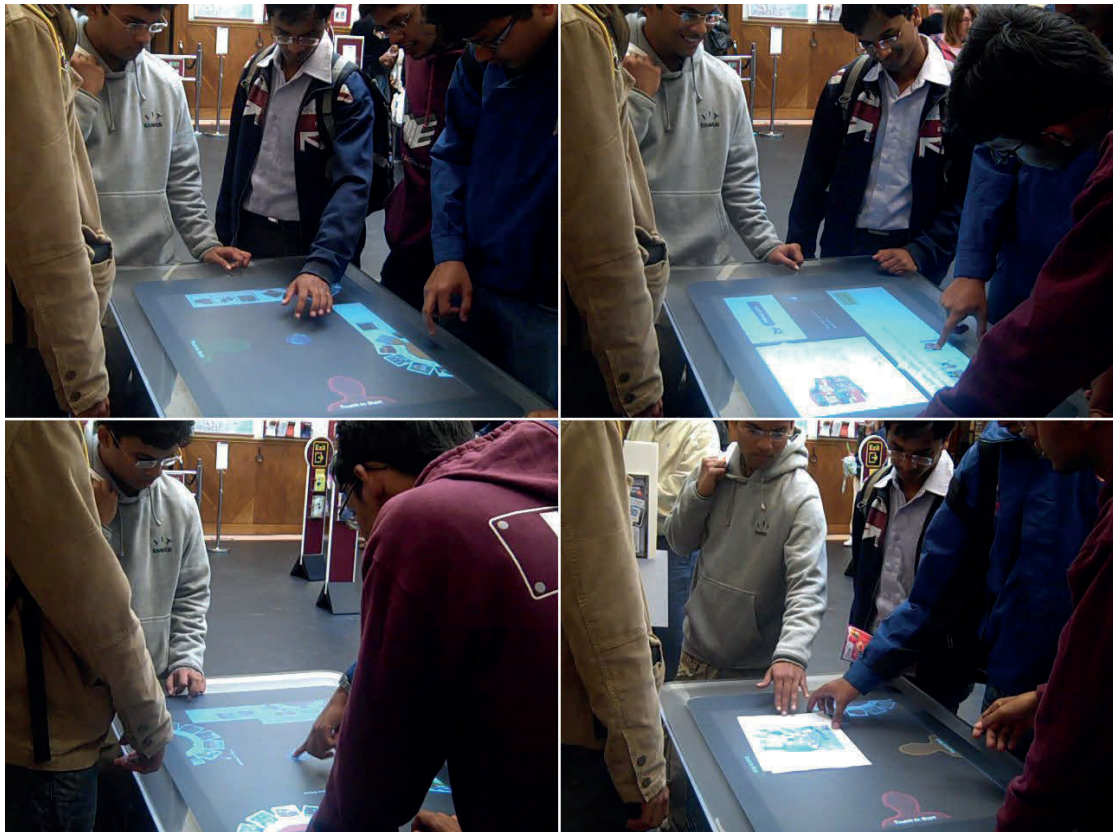


Figure 8.20: A group of five men use the tabletop. Frame 1 – two of the group are driving in C1 and C4. Frame 2 – the driver in C4 has pressed next step, the driver at C1 then takes over the interaction on the review screen and an observer and the C4 driver reposition to better orient around the review screen. Frame 3 – the group reset and carry out another session with all four carousels in use. Frame 4 – the group print out there itinerary and study it on the tabletop.

Typically, as users understood the application flow better, their use reflected the anticipated use more closely. Groups were often quite excited about do-overs, and were keen to see what impact different decisions would have over their resulting plans.

Do-overs could also occur as more members of the group were attracted to the table, and the strategy changed to accommodate more people interacting and more opinions being introduced.

8.6.7 Touch Maps

The application recorded the touch interactions as the system was being used.

The three images below show heatmaps for every touch start, drag, and release event during the study. The bottom of the images is C1.

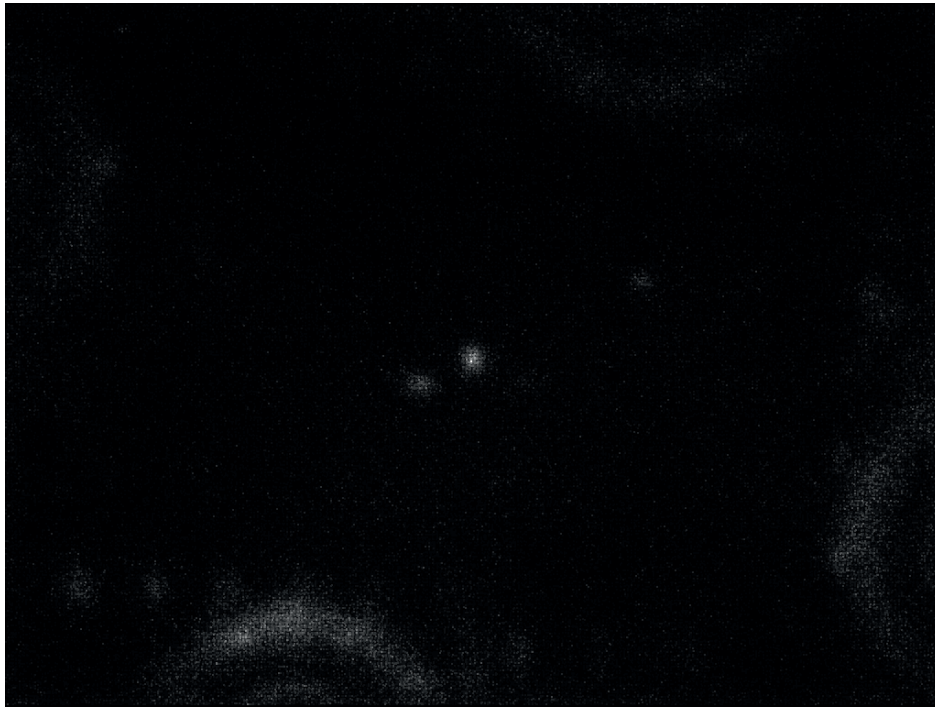


Figure 8.21: Touch start



Figure 8.22: Touch drag

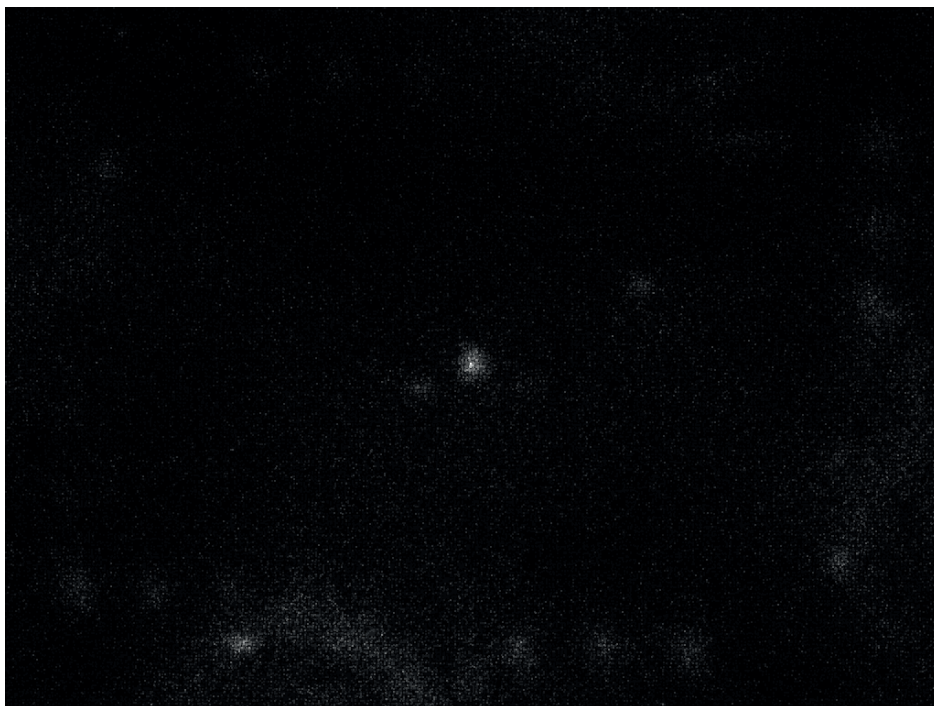


Figure 8.23: Touch release

As expected, the images show brighter areas for C1 and C4, as these were observed to be the most used carousels. This is mainly due to the fact that these were the open edges and were facing the entrance, so they were natural targets

for new users. The touch release image also shows hot spots where the cards were dragged into their selection containers. It also shows that the shared area in the centre was used a great deal, with diffusely spread events.

8.6.8 Formations around the Table

The most commonly used orientation was the C1 position, followed by the C4. This makes sense as these were the 'open' positions and the first ones reached from the entrance. A common pattern was for the more confident visitor to start interacting with their partner observing over the shoulder. Once partly in the flow, the observer could transition into an active user, most usually by taking one of the neighbouring carousel positions.

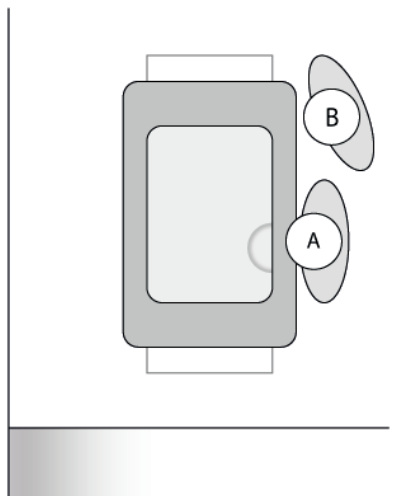


Figure 8.24: Classic user orientation, with user (A) driving C1 and observer (B) behind right shoulder

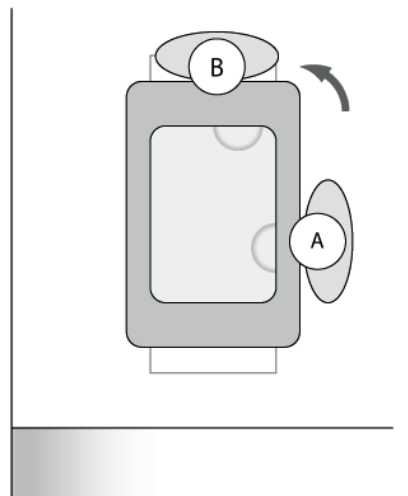


Figure 8.25: Example of an observer becoming a user (B), positioning to closest carousel (C4)

If the observer was not confident or motivated enough to initiate their own interaction, they would still provide input to the interaction by giving advice and instructions to the user. This is an example of interactions in the system happening 'inside' and 'outside' the interface simultaneously. The 'observer'

might be taking in information more widely and picking up on other cues whilst the 'user' is more engaged in operating the tabletop.

The role of the users who begin interacting first might change as members of their group join them. For example, they may stop driving their own interaction whilst they bring their colleagues up to speed with the interface. There were many permutations of observers and users, with some being more active than others. The design choices which resulted in an application that supported asynchronous joining and independent use seem to have been successful in supporting this use case.



Figure 8.26: Six people use the tabletop simultaneously using four carousels.



Figure 8.27: A group of four people using one carousel (C1).

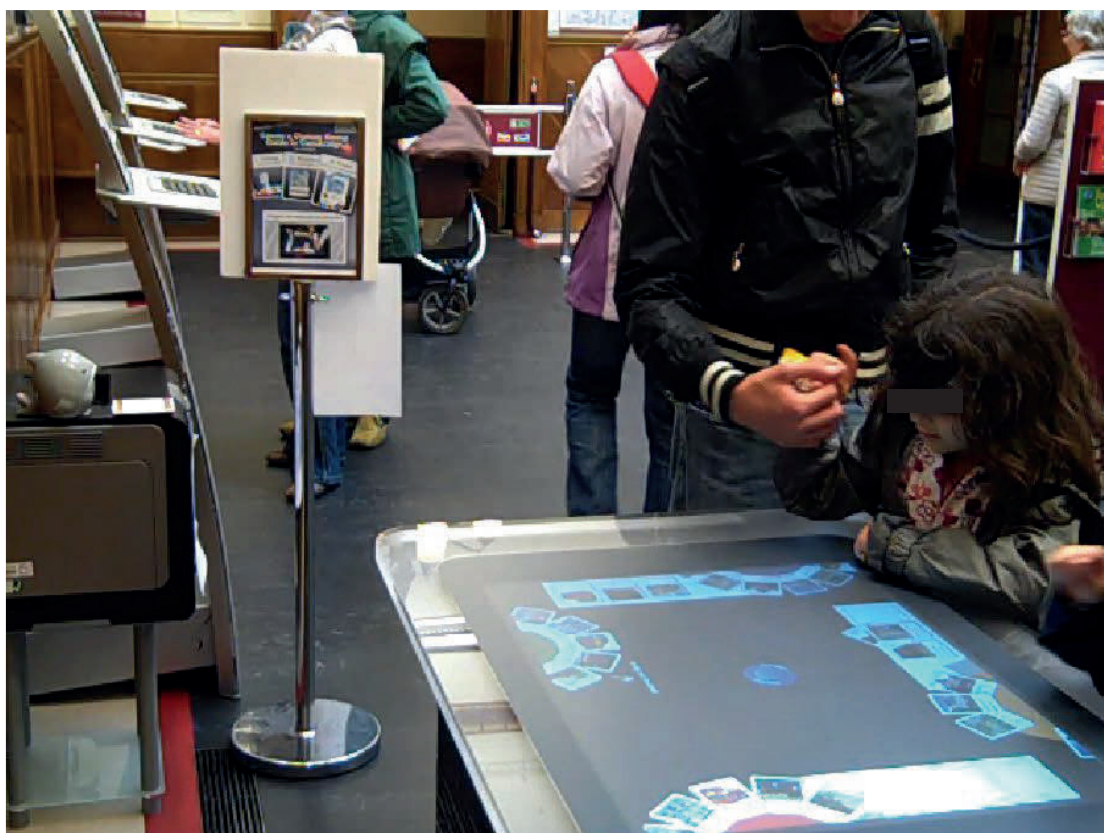


Figure 8.28: Young girl's brother pushes her hand away to take over her interaction.



Figure 8.29: Three users share the table, two positioned at C3 and one at C4. The user at C4 is comparing information with a brochure.

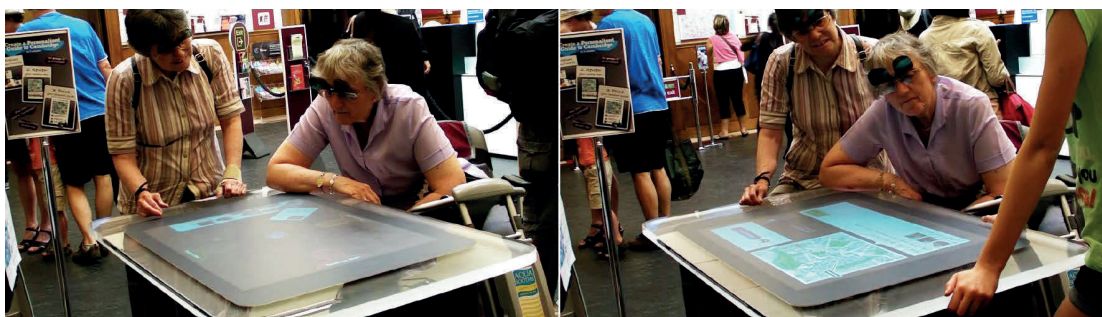


Figure 8.30: A woman in a wheelchair and her friend use C4 and move slightly on the review screen.



Figure 8.31: A group of four women use three carousels and one woman stand in C1/C4 position and uses a brochure.

8.6.8.1 *Flexible Driving*

When multiple users were active on the interface they were not exclusively engaged with their own space. Their peripheral awareness of the other users sometimes led to them engaging across the table.



Figure 8.32: A pair of users cross over spaces. They initially use C1 and C4 individually. In the left-hand frame the C1 driver shows a card to the man in C4 and they read together. In the right-hand

frame, after deciding they are interested in that attraction the C4 driver takes the card (from C1) and drags it into the appropriate box.

Occasionally, this was because one user was 'stronger' in using the interface and finished more quickly, and would take over the other carousel in order to proceed to the next step without frustration.

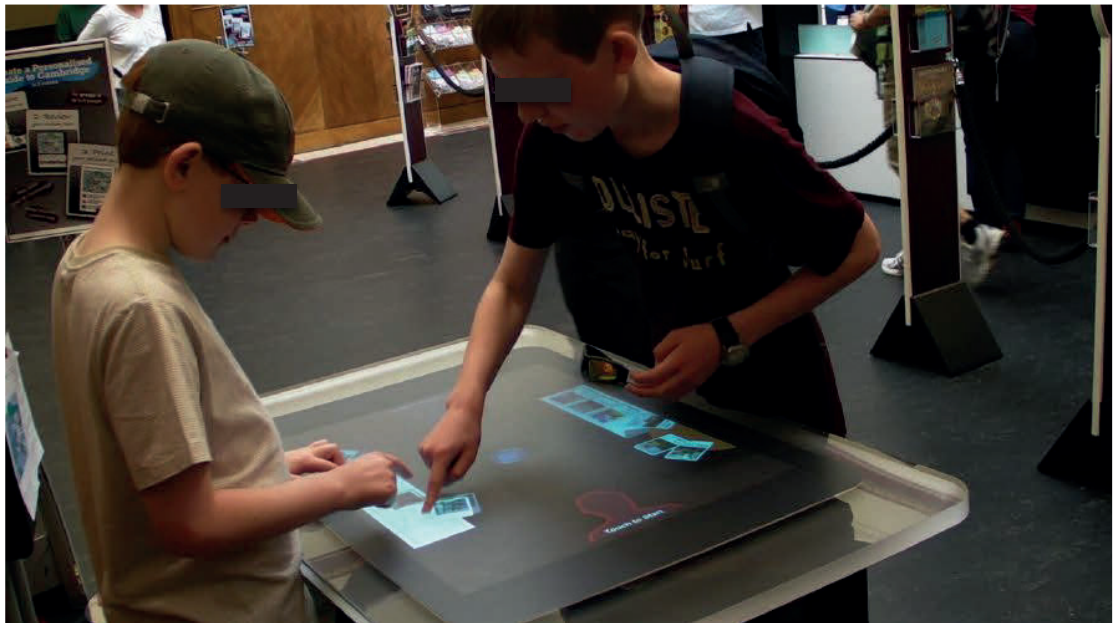


Figure 8.33: A child drags cards in to his brother's boxes in a display of impatience.

Users mediated these interactions in many ways, typically resolving it between themselves. The image above shows an older brother exerting some dominance over his younger sibling and the younger brother being passively compliant. In other examples, the user who was being invaded resisted, either verbally or by pushing the intruder's hand away.

8.6.8.2 Active Observers

Observers take part in various degrees. Some simply stand and watch silently, possibly paying attention only sporadically whilst reading brochures. Others pay attention closely and interact slightly by pointing at things on the tabletop and making verbal suggestions. Some interact fully, sharing the driving role

with the main user, or do occasional tasks, such as pressing the next step button. This suggests that the main driver is more focused on their personal area, whilst the observer takes a more general view, and is more likely to notice the next step button in the middle of the screen.

Users often took out cards and rotated them and positioned them close to the observer for them to read more easily.

Many people who used the tabletop in this configuration were couples who wanted to make decisions jointly. However, they were still able to interact with the table equally (equity of interaction) as opposed to using the kiosk.



Figure 8.34: A pair of observers study the review screen whilst one points at the time required readout.



Figure 8.35: One person drives the interaction at the review screen whilst two observers are stood at C1/C4 and C3.

The ability for users to take roles in the collaboration at different levels of engagement is an encouraging sign, as those not directly interacting with the interface are able to take a more reflective view, perhaps considering other factors which affect their plan. Their ability to then discuss this among the group might result in a better outcome than if only one level of the plan is being considered.

8.6.8.3 Direct Observers

Some visitors engaged with the users at the tabletop directly without engaging with the system. This might be by passing information from the brochures verbally to the user, or through being relayed information from either source by the user.



Figure 8.36: Woman explores application with left hand whilst holding several brochures in her right hand. Her mother joins her as observer and they compare information between brochures and on-screen cards.



Figure 8.37: A young woman drives an interaction at C4 whilst a member of her group observes over her left shoulder. The third member of the group turns around to become an observer over her right shoulder. In the last frame they are all seen reading a printed map after a successful interaction, all from the C4 end of the table.

8.6.8.4 Observers to Drivers

Frequently, observers transitioned into active drivers after a period of time watching the tabletop in use. This would tend to happen after a variable period of time, but generally enough for the observer to watch and learn how to use the interface. Once their confidence was sufficient, they crossed the ‘threshold of interaction’ and began to interact directly with the tabletop. This could be either by starting their own session at a new carousel position, joining another user at

a carousel (typically someone with whom they are familiar) as a co-driver, or by taking over an existing session from another user.



Figure 8.38: A woman moves from observer to driver. Frame 1 – She joins partner and observes. Frame 2 – She explains the application to another member of the group who becomes an observer. Frame 3 – She grabs a card and her partner steps back, ceding the driving position. Frame 4 – she moves across to take parallel position to drive. Frame 5 – she blocks a man, who is another member of the group and an observer, from interacting in her 'zone'. Frame 6 – she makes a hover gesture to signify protection of her 'zone'.

8.6.8.5 Drivers to Masters

If the group has several members who join asynchronously, another pattern which was seen was for people who were drivers becoming 'masters.' In this

role they typically withdraw from the interaction but remain active as instructors and scaffold the interactions of the new drivers, as well as trying to orchestrate the scene. In some cases people were observed making several role transitions from observer to driver to master.

As people gained confidence in using the interaction they were more likely to cede from the interaction, or share their attention in order to instruct others and be facilitative.

8.6.8.6 *Reorienting on Review Screen*

One of the research questions stated in the design of the CamPlan application was to observe the effect of transitioning between stages of the interaction flow with different cues to orientation. The intention was to signal the change in collaborative need in that stage of the application. Whereas the first stage allowed for parallel work with the option of cooperative interaction, the second stage was intended as a funnel to bring the group together to work collectively.

The cues to orientation were very strong, with the carousels being aligned to the four edges and cards being able to rotate to arbitrary angles. The review stage had cues such as the map, the top-to-bottom structure of the screen, and the cards being fixed in the canonical orientation, all of which contrasted the previous stage.

The effect was that we commonly saw users realigning themselves to the C1 edge in order to be able to read the screen more easily. People who then restart the application and start a new session typically go back to the positions they were in before.

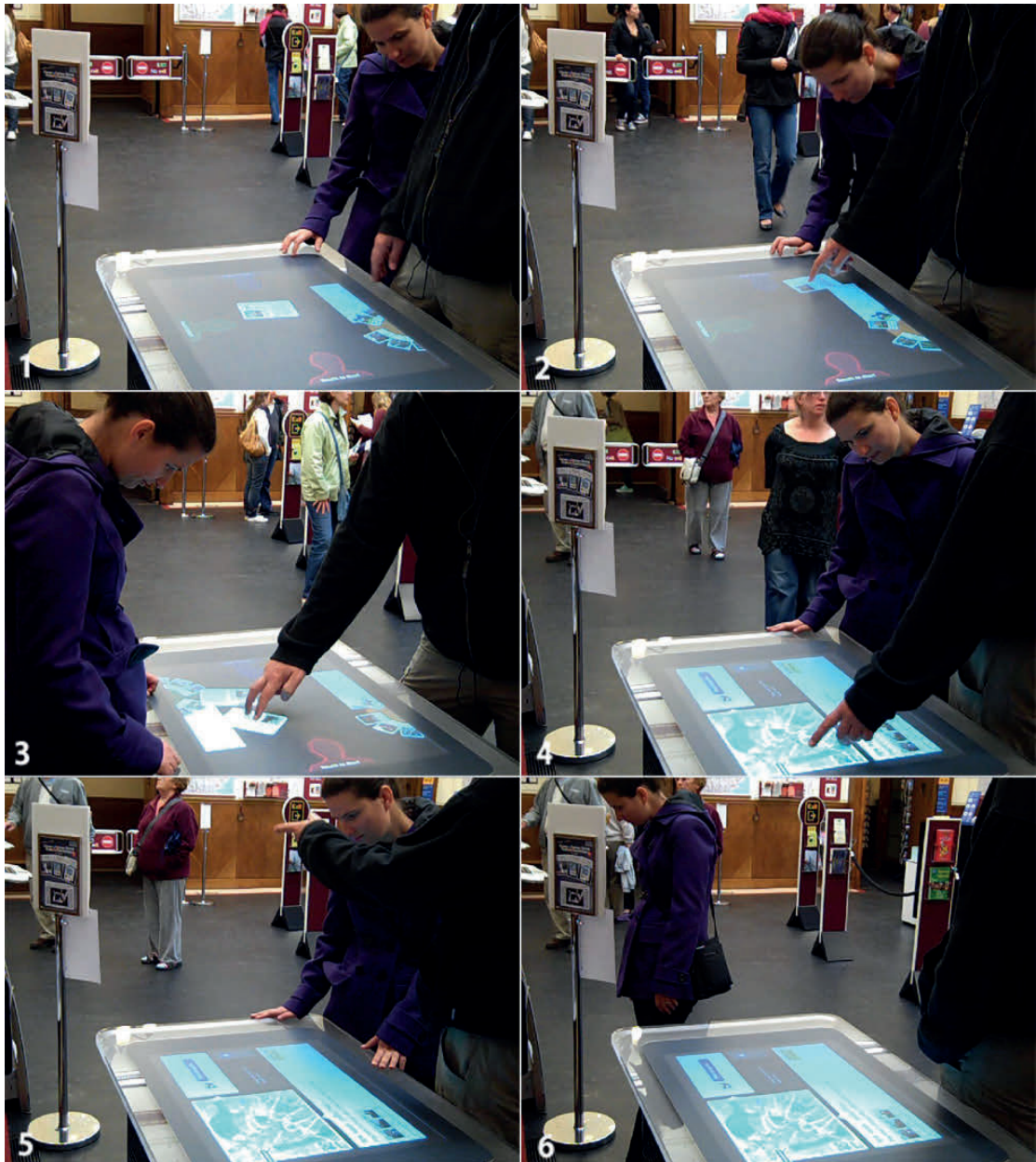


Figure 8.39: A pair use the tabletop. Frame 1 – the woman joins the tabletop in the classic observer position. Frame 2 – the man drags a card to the corner of the table to make it easier for her to read. Frame 3 – the woman starts her own session at C3, the man rotates a card from his deck around for her to read. Frame 4 – the woman reorients herself to the C1 position on the review screen. Frame 5 – the man points to the printer when they discuss the option of printing. Frame 6 – she goes over to the printer to study the example map and printed sheets attached to the printer.

The user positioned at C1 when the transition occurs is in a privileged position as far as access to the application goes at the stage in the flow. How users adapted to this varied. At times, the user would step up to a leadership role and

organize the interaction from this point, regardless of how verbal or active they were in the previous step. They would take charge of the screen and be the most active driver. Other times they might abdicate and yield their space to a more dominant group member who would take the central position at C1

8.6.9 Personal Space

Users were frequently seen to push away the hands of other people who tried to interact in the same space as them. Typically, the person interacting in that position first retained dominance over that area.



Figure 8.40: A user pushes away the hand of his companion as she attempts to grab a card.

The degree of overttness in the physical gestures varied, with younger users being more expressive. In the figure above, the man nudges his partner's arm with a small gesture with his wrist and elbow. Below, the children were much more obvious in their gestures.



Figure 8.41: A girl grabs her sister's arm and moves it away.

The boys were typically more rough than the girls.

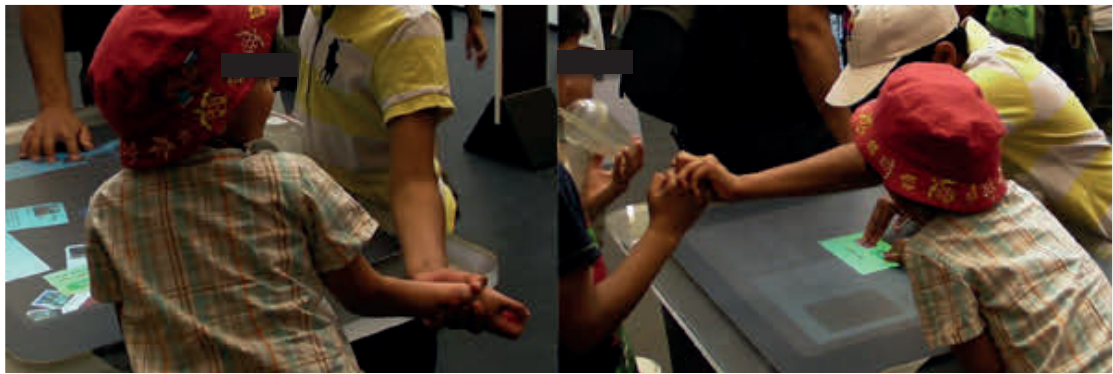


Figure 8.42: A brother attempts to physically dominate the interaction over his brothers.



Figure 8.43: A woman using C1 prevents her partner from starting a session at C4. He then 'steals' a card and tries to lift her hand.



Figure 8.44: A brother uses C4 and his sister tries to join in. He pushes her hand away and makes a gesture suggesting that she start her own session at C1. She then does and presses 'yes' on the next step prompt for him.

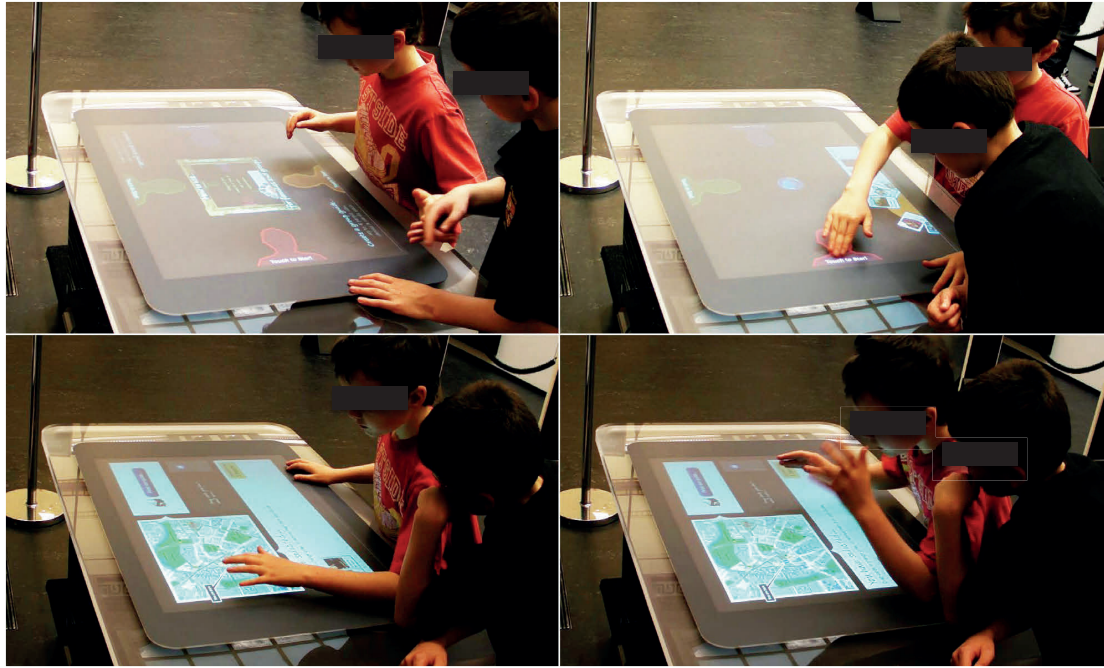


Figure 8.45: Two brothers interact whilst using the table. Frame 1 – the brother positioned at C1 pushes his brothers hand out of the way as he tries to use the table. Frame 2 – the brother starts a separate session at C2 for his brother. Frame 3 – on the review screen the C1 brother puts his arm across the table between his brother and screen. Frame 4 – he raises his arm after his brother tires to reach over.

This raises many questions such what is acceptable in terms of allowing users space for their own interactions and what is an appropriate ‘guarding’ response. Users’ sensitivity to intrusion generally seemed more acute when they were still adjusting to the application, indicating a possible effect of comfort level, or perhaps they wanted space if they felt overloaded by the demands of the task or the interface.

The more confident users of the system would be more likely to intentionally interrupt another user’s interaction, or an observer who is not as committed to the application might interrupt as a way of getting attention. Generally, the interruptions were friendly and playful, although clearly some personalities were not well suited to this manner of frustration.

Children close in age were much more likely to physically restrain each other, as observed in the OurSpace studies (Rick *et al.*, 2009).

8.6.10 Reading Pose

When users are confronted with a new screen in the application flow, or when they wish to read a longer portion of text, they are likely to place their hand on the edge of the table. This can be either resting on their knuckles or on their palms but they are often seen with taking a dominant position with both arms on the edge of the table and slightly away from the screen. This may be to allow them to lean over the screen to afford a better view, to signify dominance over the screen, or at least the 'personal zone', for comfort or to keep their hands away from the screen in case of accidental interruption.



Figure 8.46: A man adopts the 'reading pose' to study the review screen.



Figure 8.47: A man pauses to consider the carousel at the start of an interaction, adopting the 'reading pose'.

8.6.11 Use of the Step

Some users put one leg up on the step. This can be seen as them making themselves comfortable or signalling possession of the space around the table. Sometimes observers who were positioned by the right-hand shoulder of people using C1 would put one foot up on the step, possibly to indicate their engagement with the interaction.

Worryingly, several people stumbled over the step; typically because they had picked up a printout and did not look down to see that their feet would collide with the bottom of the step. This was partly due to the construction of the frame and could be helped in a future design by removing the lower supports for the step, or making the step narrower. Thankfully, no one was hurt.

8.6.12 Expressions of Joy and Surprise

It is pleasing to see users who express delight when using the application. Users have been observed gasping in delight, expressing verbal joy (“this is so cool”) and smiling and inviting others over to observe and join in interacting with the tabletop.

This is also a good indication that the application is a successful design as joy is an indicator of resonating with people and an important motivator for people to keep using an application. Indicators of approval and fun included:

- Physical expression of delight
- People taking photos with the tabletop
- People bringing others over to show them the tabletop
- Verbal expressions of approval: ‘It’s well done, no?’ and “That was cool!”



Figure 8.48: A child expressing joy bordering on disbelief.



Figure 8.49: A young girl swings around to express her delight to her father after dragging cards into the boxes (an unrelated man studies the example printouts on the front of the printer in the background).

Several users expressed delight in the wobbling motion of the cards which happens when a user attempts to drop a card from one carousel onto another user's area. The card animates back to the source carousel whilst wobbling as though shaking its head. This is a light-hearted and humanising gesture that seems to delight.

8.6.13 Interruptions

Users are sometimes interrupted by an external event or take themselves away from interacting at the table to look at a brochure or to talk with someone else in their group. The tabletop application reset itself after a period of time if no input was detected, displaying a message first prompting the user to confirm that they wanted keep the session, otherwise resetting to the attract screen.

Users were fairly able to recover from interruptions as their interaction could be partly ‘eyes-up,’ keeping their hands on the screen in the same position whilst looking up to respond to questions, for example.

One form of interruption which did cause a fatal problem was when two or more people who were not in the same group tried to use the tabletop simultaneously. This happened a few times during deployment and would typically lead to confusion, mostly at the stage when one person would want to proceed to the next screen and the ready prompt was shown to all users. This is a problem that would have been interesting to try and design a solution for had we had more time.

Collisions which occurred between users who were in the same group were typically dealt with more easily, either with a verbal rebuke, or physically pushing the collider’s hand away. By assuming that users were of a coherent group that knew each other before they used the tabletop, we were able to ignore the problems of awkwardness that can occur when strangers collide when using a tabletop.

8.6.14 Fluidity

The fluidity heuristic was used in considering the design of the application. High fluidity is a state whereby the users of an application are able to spend a higher proportion of their time in a higher cognitive state (i.e. considering the complexities of their problem) as opposed to dealing with lower-level technicalities of using the technology.

The ability to quickly understand the application flow and interaction methods allows the user to form a high-level goal in line with the affordances and the

proposition of the tabletop. That is to say, a high degree of fluidity can only be achieved if the performance of the system and the users' expectations are aligned.

One aspect of a multi-user system is that users will vary in the degree to which they are naturally comfortable working collaboratively. By this it is meant that working on the problem using the application directly through the interface represents one demand on the user and interacting with other people represents another demand. It is assumed that users will vary in how well they are naturally able to manage both demands simultaneously.

When the demands of using the interaction are relatively high (e.g. when the user is novice), the likelihood of them becoming overwhelmed by interactions 'outside' the interface is higher. This was observed in people who would be using the application and 'shush' or 'shoo' people who would come and talk to them. If the other person persisted then the user would wait until they reached a comfortable, stable state, before turning their attention to them. This contrasts users who were able to rapidly gain comfort and mastery in using the system who could use it independently whilst holding a conversation, monitoring other users, or helping others.

The presence of sessions where users were able to deal with interruptions and to switch between working at the table and to hold conversations with multiple people in a noisy environment is an indication of a high fluidity. The ability to be reflective about the task requires shifting between various levels of perspective, from detailed to overview. In this way, a fluid interface supports reflection, which may result in better outcomes. This seems a natural fit for tabletop

computers and their proven effect on collaboration, as alternative perspectives of various collaborators can be considered.

8.6.15 Misunderstandings

Many users were observed double-tapping and attempting to pinch-zoom the cards when they were in their expanded state after being removed from the carousel. This shows how these two gestures are very common in the users' mental models of how to interact with computers, the former being from desktop paradigm with mice and the latter from touchscreen devices. It is clear that this gesture is used when the user is either exploring what gestures are supported or directly searching for more detail than is shown on the expanded card.

They typically attempt these unsupported gestures several times. They attempt more if their previous interactions have had a low success rate, i.e. if they have had previous problems with finger registration, as they may not know whether they are being unsuccessful because the gesture is unsupported or because the tabletop has not recognized their gesture.



Figure 8.50: A woman turns her hand outwards to indicate confusion as to why her finger is not registering a touch.



Figure 8.51: A mother and son use C3 and C1 respectively. She attempts to put a card she has chosen from her carousel into the C1 boxes of her son. He points at the space where her boxes will appear when she releases the card.



Figure 8.52: A user attempts to pinch-zoom the map in the review screen

One man, having walked over to see somebody else put some money in the donation box and collect a printout, proceeded to put money in and waited to receive his printout. Clearly he had made a large misunderstanding and was expecting something akin to a map vending machine. He was not seen to observe the previous interaction with the tabletop and did not seem aware of the fact that the printer was connected to it.

One user, who was using the tabletop alone in the C3 position, made his selections then went to the review screen. He then attempted to rotate the whole screen using a two-handed gesture to orient the screen towards him. Being unable to do this he did then walk around to the C1 position. It was considered whether to facilitate this gesture, or to automatically reorient the screen towards C3 if a single user works from there. However, because this would require redrawing the print screen because of the directional arrow, it was deemed to be too much work for a small pay-off.



Figure 8.53: A man attempts to prevent cards from floating back to the carousel by holding three cards with his hand.

Users seemed to be confused by the location of the printer. After pressing print and confirming, many seemed to then expect the printout to emerge from the side of the device. This was not helped by the fact that a blanking plate of the Microsoft Surface which was intended to house a DVD drive looked as though it might be related to printing. Some additional instructions or a diagram may have reduced this confusion.



Figure 8.54: A man points to the side of the Surface after pressing print, expecting the printouts to emerge from the side of the table.

The addition of small 'bubbles' that appeared on screen when a user touched it helped in reducing confusion as to whether a finger input was registered by the system or not. This was a feature which is included in the Surface SDK (SP2) by default, but had to be replicated manually since we were not using that SDK.

A small animation was added to cards when there were dropped onto selection slots other than those attached to the carousel they came from. The card would rotate side to side or 'shake its head' whilst translating back to its position in the original carousel. This human-like behaviour was enjoyed by many users.

Not every user appeared to understand immediately that the carousel could be rotated. It was hoped that this affordance could be communicated by showing part of a card with the rest concealed off screen. However, many users were observed discovering that the carousel rotates when attempting to drag a card out. The motion of the other cards which commonly happened when pulling a card out was enough to convey this affordance.

After adding the 'drag a card' instruction next to the carousel some people were observed tapping this text. Although it was not interactive and was meant to be interpreted and used with the carousel, several people attempted to tap it. This is likely to be due to the fact that people did not read it very carefully, perhaps seeing an action word, and, being used to clicking buttons with action words on traditional PCs, trying tapping as a default satisficing behaviour.

Several people were seen to tap on the video on the attract screen. Perhaps this is due to people being drawn to the motion, wanting to 'take-over' or use the system as they would a game.

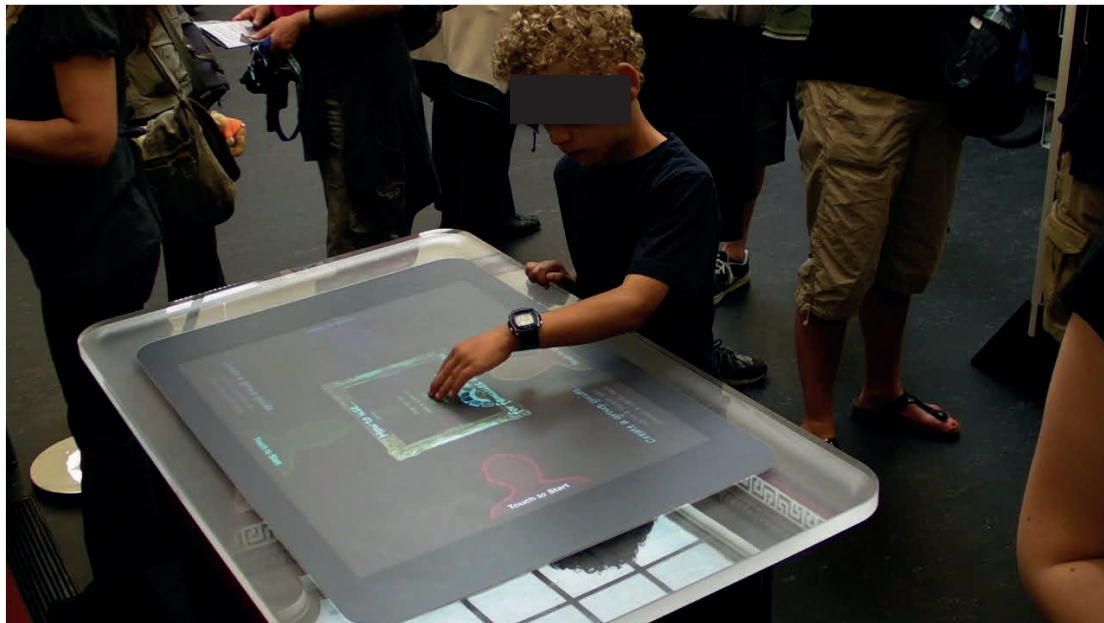


Figure 8.55: A child taps on the video on the attract screen

8.6.15.1 Collisions

One of the major breakdowns of the system was when two or more users who were not from the same group attempted to use the tabletop simultaneously. This led to confusion, especially when one user wished to proceed to the next

stage (the review screen) and the other user(s) would be interrupted by the confirm dialog box, and by having what they were doing before that frozen.



Figure 8.56: A young girl has come over and started using the tabletop at C4 whilst a man who was previously engaged in a session is at C1. The man has pressed the next step button but the girl is not aware of this, as she is engaged with moving cards around. This results in the man leaving the tabletop.



Figure 8.57: Three unrelated users are using C1, C2 and C4. In the left-hand frame the user at C4 turns his hands outwards to express confusion as to why the screen has changes from select to review after the man in C1 has pressed next step. In the right-hand frame the man from C4 is seen to take over the interaction after users at C1 and C2 leave following the collision.

Compared to some other studies such as the seating plan study (Marshall, 2008), there were less direct collisions in terms of accidental hand touches or interacting with the same on-screen object. This could be due to two factors: the fact that the carousels contained individual decks of cards; and, the objects were larger than those in the seating plan study.

8.6.15.2 Dealing with Input Recognition, 'Finger Problems,' and Lag

Occasionally, users were observed waiting after an attempted gesture to see if tabletop responds, presumably assessing if the system has registered their input but has lag. After a few seconds they then will retry the gesture if it has failed. When they retry they may try again with different finger style, such as using two or three fingers or even trying their palm. This was one of the main faults of the system and the one which most frequently caused frustration.



Figure 8.58: A young girl uses two hands to overcome finger recognition problems.

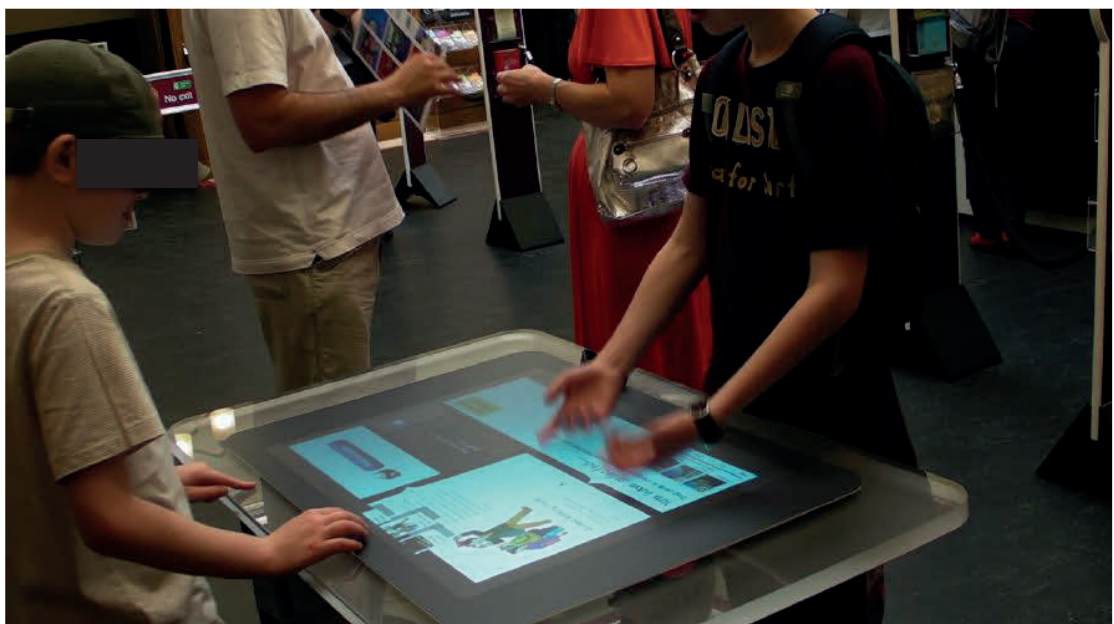


Figure 8.59: The child on the right hits the table with the backs of his hand in frustration and disgust after it crashes following a session of play with his brother.

Although users appeared to give the technology some leeway initially, perhaps because they were making allowances for the fact that they had not used this class of device before, not all would persevere for very long if they encountered difficulties.

8.6.16 Unanticipated Uses

A few users were observed operating more than one carousel in order to choose more than three cards. Typically this would be an individual who had gone through the application flow once, then reset and decided to select more cards to get more information on their printout.

Some users were content simply reading through the short descriptions on the cards, moving on to other parts of the information centre afterwards without printing out their guide.

Others still added cards and proceeded to the next stage in order to see them on the map. After studying the map they would either head to the counter or leave the centre.

A common sight was to see users comparing the information on screen to information they had already obtained: either printouts from home they had brought with them, maps from the counter, or brochures. The discussions suggest that they were looking for attractions which they may have overlooked. These visitors appear to have been careful planners and were inclined towards considering all options to ensure they have the best information to choose from.



Figure 8.60: A couple compare the brochure and the tabletop representations of the Round Church attraction.

People used the application to various degrees of completion. Some used the application entirely, resulting in a printout. Some went as far as the review screen and would use the information there to go to the counter, or be satisfied with what they have learned.

An example of someone using the tabletop as an information resource.

13.54 14/5/10 - From Notes

A woman in her 20s and by herself walks straight up to the table. She has no problems in using the system and quickly chooses three cards, without reading the short information. She then goes to the review screen and reads the detailed information about all three chosen cards. She then resets the system and goes over to the counter.

Another example:

11.40 31/5/10 - From Notes

An elderly woman browses through the carousel, looking at the attractions. She drags out the 'Backs' card (a section of open space along the backs of the colleges) and reads the text. She then goes over to the counter for more information, ending up with an annotated map from the IA.

An example of people using the tabletop as an 'online' planning resource.

11.05 13/5/10 - From Notes

People viewing the map:

"we can do C then D"

"well, yes"

"or what if we do B, then C and D"

"that makes it easier then"

another example:

11.55 20/5/10 - From Notes

A woman in her 20s by herself comes over to the table with some paper in her hand. She chooses three cards carefully, reading the text of each one she selects from the carousel. She then looks at the map and compares it to the printed map she was carrying in her hand. She then resets the application and leaves the VIC.

Two times, people were seen to take a picture of the map using a mobile phone camera.

12.20 14/5/10 - From Notes

A young man (1) who uses the system once, then calls an older man (2) over to begin a session together.

Young Man is driving the interaction at C1 and the older man is observing over his right shoulder.

(1) "King's College Chapel, yeah?"

"that one there is the Backs..." [(1) is choosing cards to show (2)]

(2) "what about..." [(2) points at another card in the carousel]

[The young man has chosen three cards]

(2) "what do you do now... oh yes" [(1) presses next step and they go to the review screen]

[They both study the map]

(2) "Well, that's alright"

(1) "That makes it easier then" [they are commenting on the relative closeness of sights they wish to see.

[They print out]

(2) "That's good, innit?"

(1) "We've got something to work from... this map is a bit bigger scale"

[They both study the printout for a while then turn back to the table and start another session. They choose the same three cards and go the review screen.]

(1) "B is the one you probably want to see" [points at card B, which is the Backs. He then reads the extended information for King's College Chapel]

(1) "Oh you've got to pay to go into King's College Chapel"

(2) "Any more?"

(1) "I'll just check" [(1) resets the application and starts another session, looking through all the cards in the carousel]

[He chooses three other cards and prints them out]

(2) "Is it printing?"

(1) "Yeah, it's coming out"

[They both take the printout and join a young lady at the other end of the VIC and show her the printouts. They then leave together.]

It is clear that some people using the VIC are using it as a way of getting more information without structure, i.e. are coming to see what's available. Others come with more foreknowledge and are seeking out specific information.

One couple were interested in the estimations of time, going around the application flow several times, selecting different cards and combinations to get an idea of how much they could see in the time they had.

8.6.17 Mixed Usage

Users reappropriated the tabletop for different purposes than intended, sometimes including other media and devices.

8.6.17.1 *It's Still a Table*

In accordance with other findings from tabletop research in public settings (Hinrichs & Carpendale, 2010) it is important that an interactive tabletop also be functional as a normal, non-interactive table. This is important as people use tables for a variety of purposes and by allowing the normal affordances of tables people are encouraged to mix the usage of the interactive and non-interactive facilities without frustration or confusion.



Figure 8.61: Three women use the tabletop as a prop for their map.



Figure 8.62: A couple use the Surface as a table for their map, accidentally triggering sessions underneath.

8.6.17.2 Combining with Other Media

Several users came to the tabletop with brochures or maps in their hands. There were several examples of users comparing maps printed elsewhere with the on screen map. Other users were seen to use the application in conjunction with leaflets collected beforehand. Leaflets were placed down on the table and cross-referenced with the online map and used together to form a journey plan.

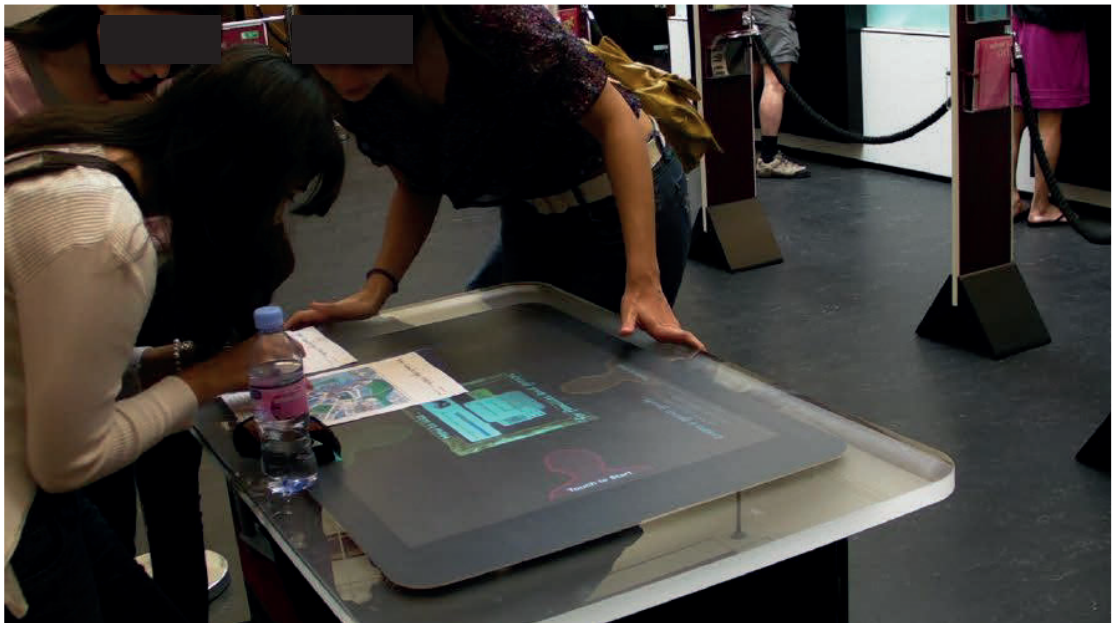


Figure 8.63: Three girls use the tabletop to study a map printed from their prior session.



Figure 8.64: A man compares notes on a printout he has brought with him and his mobile phone.

In the above figures users are observed aligning different representations of similar information. That is to say, they have printout with text, maps, and information on their mobile phones, and they are connecting the various sources together so they are able to use them together to plan effectively.

Providing information in a format which is easy to translate into other common forms of information, e.g. map-based guides, descriptions of attractions with common information etc. is an important factor of the application output.

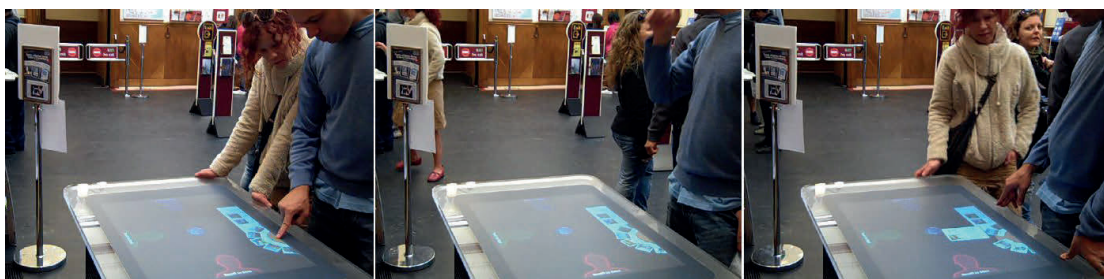


Figure 8.65: A couple use the tabletop. The woman, who was previously using a kiosk, goes over the kiosk to check the name of an attraction, then returns to read the information about that attraction on the tabletop.

Several users were observed comparing information between the kiosks and the tabletop. They would finish with the tabletop, commonly taking a printout, which suggests that the ability to organize and print out is valuable.

8.6.18 Play

Many users engaged with the application in a playful way. This behaviour was observed in both adults and children. Children were commonly seen to run excitedly up to the table and start playing and exploring. Parents would then join them and either observe, try and scaffold them, or take over the session. Otherwise, parents would leave their children occupied with the table whilst they visited the counter or explored the VIC, happy that the table was keeping their children busy and in a fixed location.

8.6.18.1 *Single User Play*

Several types of play were observed, such as ‘structured’ or ‘kinetic’. For example, structured could involve users playing with the cards and trying to match them from different carousels or line different cards up neatly on screen. Commonly kids were seen to engage in kinetic play and try and spin the carousel quickly, or rub their hands over the surface of the screen.

8.6.18.2 *Paired or Group Play*

A common game was ‘snap’–matching cards from different carousels. This involved them finding the same cards from their carousels and dragging them out and putting them next to or on top of each other, sometimes actually calling out “Snap!” This supports the design choice that the attractions were based on cards and this metaphor translated to the users.

One pair of children was observed adding the same cards to all the boxes. The boy said to his sister, “you need to get all of these to match,” indicating what he understood the purpose of the application to be, as a game.

8.6.18.3 *Mastery*

Some users, especially children and teenagers, showed a desire to master the interface. Once they had learned the basic concepts they then showed more experimental interactions.



Figure 8.66: A child uses his elbow to drag a card



Figure 8.67: A child drags four cards at once using four fingers



Figure 8.68: A man uses three fingers to drag three cards out of the selection.

Users would experiment with different gestures to see what could be understood by the system, and to test the thresholds of input registration. Those who were most inclined to mastering the system would go through the application flow several times trying different combinations, inferring the logic of the application in order to increase their understanding.

8.6.19 Abandon

People leave either because they don't seem to have understood the proposition of the table, or because other people in their group are not as interested. Sometimes people who were using the tabletop were pulled away when the others members of their group left. Perhaps attracting and capturing the interest of others (perhaps a soft sound) may be important in retaining users.

People who leave the table before completing the application flow would often ‘tidy up’ the screen before leaving. This could consist of putting the cards back in the carousel or pressing ‘start again’ to restore the application to clean state for the next user (whether there was one waiting to use the system or not).



Figure 8.69: A child reaches across the tabletop to reset the application after he and his peers are called to leave by their guardian.

8.6.20 Languages

Many languages were heard including Italian, French, German, Hebrew, Chinese and Japanese. Supporting more languages might be a future option for developing the application further.

More generally, the content could have been more varied based on some feedback: “This is very cultural the stuff in here” says one user to a group away from the table, “no, like, bars.”

8.6.21 Interest in the Tabletop

There was a significant amount of interest in the tabletop, which is evidence of the appeal of the technology and the choice of application. It was covered in the local TV news and the local newspaper as well as usabilitynews website⁷.



Figure 8.70: Local television making a segment for the evening news on the application.

The appeal of the application was also confirmed in positive statements made by the users whilst using the application. For example, one mother saying “we liked this one,” and “it’s fun” to the camera, whilst using it with her children. People were also interested in taking photos of themselves using the tabletop,

⁷ <http://usabilitynews.bcs.org/content/conWebDoc/41585>

indicating that it is special or unusual enough to warrant sharing or remembering (see below).



Figure 8.71: A woman takes a photo of her friends using the tabletop.



Figure 8.72: A father takes a photo of his daughters using the tabletop.



Figure 8.73: A group have their photo taken with the table.

8.7 Discussion

One of the most interesting factors of this study was observing how people approached the tabletop. The findings of Brignull & Rogers (2003) were seen to be in place in this study: namely the honey pot effect, and the threshold of awareness and thresholds of interaction. As people entered the VIC, they might not have initially been aware of the tabletop. As they approached the corner of the room, they may have seen the signs, or observed other people using it.

According to the honey-pot effect, it is more likely that a new user will start interacting with the system if they observe people using it previously, and this was found to be so in this context.

The signs and presence of people using the tabletop may have raised the new user's awareness of the system and led them to consider its value, and whether or not to use it. If they consider the application, see it in use, like its appearance, and understand that it will be of some use to them, or will be enjoyable, then they reach the threshold of interaction and plan to start using it.

Extending this pattern, once they decide to start to use it, it is crucial to provide a series of small successes to help motivate the user and scaffold their understanding of the interactions and flow of the application. This funnel of awareness, decision to interact, and then initial successes, is similar to the conversion funnel in e-commerce. That is to say, a percentage of potential users will be lost at each stage of the approach and initial interactions.

There are many potential factors that we can hypothesise are important, such as modelling this funnel and other factors which determine the rate of uptake of the application and its success. These include: age, previous experience level

with similar devices, dominance within the group, competition for attention and distraction, the length of the queue for the counter, the presence of people already using the tabletop and their apparent level of interest etc.

Some visitors to the VIC may not register the presence of the tabletop and pass it by, perhaps mistaking it for just a normal table. Those who see it and apprehend that there is something unique about it may attempt to understand what value it has to them, but decide that they are happy with what they have already achieved towards their goal of planning (e.g. have brochures, or already be in the queue to speak with the IAs). They might feel that attempting to use the tabletop will be difficult, or that they might feel embarrassed if they appear clumsy. This is likely to be even more of a discriminating factor if there is no one using the tabletop. If they are using the tabletop, then they are able to observe its use and learn enough to feel confident in taking on their own session when the current users are finished.

It may also depend on the composition of the group, the intentions of the group members, and the dynamic between them. For example, a family of four might be led by their father who intends to get a map from the counter and get out. However, the children, not being so singly-focused, may happen across the tabletop and be excited to use a large touchscreen. Their interest may lead to the mother attending to the tabletop, helping, and perhaps becoming involved herself, whilst the father is at the counter.

One of the aims of the application was to make the process of planning a day out in Cambridge more equitable for children, as several factors meant that the existing experience was not well suited to kids' participation. The height of the

brochures, the counter, and the kiosks all meant that smaller children were physically discounted from the information centre experience. However, children appeared to be instantly comfortable with the tabletop, and the design of the application meant that everyone had equal opportunity to make choices in the plan. It would be interesting, for future work, to follow groups of varied ages around on their day in the city and see if their plan was actually carried out, or if the children's choices were ignored by their parents. The lower cost of interaction, i.e. placing a card in the selection box, means that children have less of a barrier to making contributions to the plan as opposed to having to make a case for their wishes verbally.

Children are likely to feel motivated to seek approval from their parents, or members of their group. Their desire for mastery of the application appeared stronger than in adults.

A lot of the decision-making in the application is implicit, which is to say that when observing users, it is hard to infer why they make decisions in the negative. For example, when choosing amongst attraction cards, they may simply pass over ones that are not interesting to them. This can make understanding the weaknesses of the system and the content difficult.

8.7.1 Issues with the System

One possible flaw in the design is the observed underutilization of the features of the review screen. These include the time readout and the additional, longer descriptions of the attractions which could be read when holding a finger on the cards. What was observed was the main driver (normally the person positioned at C1 when the change between stages occurred) was focused on the card

representations. It was commonly one of the observers who first noticed the time readout, or understood the capability to take cards out of the plan. It would be possible to test a small tutorial that provided contextual tips on the review screen to bring attention to these elements, but this has to weighed against the cost of slowing down the interaction and potentially frustrating the users.

8.7.1.1 Finger Registration

Although the Microsoft Surface was one of the most popular commercial tabletops at the time, there were some issues with the reliability of the touch input. A significant proportion of the users encountered issues with touches not being registered, jittery tracking of drag gestures and false positive touch events. This was despite regular and careful calibration of the touch recognition system by the experimenters. The tabletop uses infra-red cameras to detect touches on the table surface which causes infra-red bottom illumination to be reflected. This is then processed in software by the attached computer.

The tourist centre had a frosted set of windows in the ceiling, which, on a sunny day was quite bright and led to some noise in the input signal. This was unavoidable, and a limitation of the hardware solution. Since we were not making use of the other capabilities of camera-based tabletop hardware, such as tracking objects and fiducials, it would have been preferable to use a more reliable input mechanism, such as a capacitive input surface (as used on devices like the iPad).

Users were able, in most cases, to work around the problems with the input system. However, these issues were almost certainly detrimental to the overall experience and frustrating for the users. Addressing this issue would be a good

measure for improving the success of similar tabletop systems which rely mainly on finger input.

8.7.1.2 Users' Understanding of the Application Flow

For naïve users, it was sometimes difficult to guess that there was a second stage to the application, and they may have thought that the carousel selection stage was all there was to the application. Although we attempted to counter this by showing the review stage on the posters, it is likely that most users did not study the posters very carefully. People wanted to see more information on the cards, and did not understand the existence of, or differences of the second step. If this application were being developed for commercial and general use this would be something to address, however, although we did conduct continuous development of the application whilst it was deployed we did not choose to implement changes of this sort as it seemed as though it would go against our research goals of seeing people work in different collaborative modes.

Another change which might have been valuable to try during the study would have been to start with the cards already shown on all the carousels. The concern of the experimenters was that this might encourage people who aren't from the same group to interact simultaneously on the carousels, only to be confused and frustrated when one of them wanted to go the review screen. For this reason, we did not feel it was worth disrupting our data collection in this study.

8.7.1.3 Colour Coding

Very few users were aware of, mentioned or made use of the colour coding of the cards on the review screen. The 4 colours were displayed as dots on the review screen card and matched the colours of the individual carousels. If more than one person chose the same card, that card on the review screen had multiple colour dots.

Some users were aware of having made choices separate from each other but this did not seem very relevant in the review screen. On the whole people remembered their choices and identified them without colour coding. The presence of multiple dots on one card might have some value, showing the popularity of that attraction, but otherwise, apart from adding colour, the dots are deemed unnecessary.

8.7.2 The Sign

Positioning of the sign was found to be very important for how people approached the table, and how much they understood about the application before engaging.

Following initial interviews that revealed that people were not aware that it was intended for multiple users, the word 'group' was added prominently to the text of the sign and a picture of four people using a Surface simultaneously was added.

The optimal position for the sign was found to be close to the outside corner of the table, facing towards the entrance. This meant that it was in clear sight of people as they walked towards the table, and also served two purposes of

altering the flow of traffic. People approaching the sign had to choose either to move closer towards the table or to go in the other direction towards the front of the queue and the counter. It also provided a form of protection for people using the outer edges of the table from traffic flowing around them.

8.7.3 Ergonomics

As Ryall *et al.* (2006) noted, the physical properties of the tabletop seemed to inform the way in which it was used. In particular, the change of height of the tabletop seemed to work well for both adults and children. People also tended to rest their elbows on the edge, which could be for comfort, and also as a way of communicating that they were engaged in reading.

8.7.4 Extending the Thresholds of Engagement

As mentioned above, Brignull & Rogers (2003) describe two theoretical thresholds to explain how people approach public technology. First they must reach and cross the threshold of awareness, and then the threshold of interaction. This can be extended to group situations, whereby the perceived value of the multi-user application to one or more members of the group might alter the group dynamic as a whole.

Once at least one member of the group is interacting, they might feel that it is worth recruiting other members of the group to join, perhaps a threshold of inclusion. Users who reach a threshold of confidence might feel that they can take over roles of teaching other users. This would describe the progression from user, to driver, to master as outlined in the observations above.

9 Discussion

This chapter consists of a discussion of the course of research as a whole, taking into account the theoretical frameworks, two studies, and contributions to the field. Topics discussed include: support for the frameworks and heuristics including the fluidity framework, the lean-observe build methodology, sensitivity to context, and multi-user activity-based design.

The Cynefin model suggests that there are four essential categories of problem which vary in their complexity. In attempting to model the problem of designing for multi-user tabletops, some previous researchers have been attempting to build a model which sits in the complicated category. However, I suggest that it is not sensible to attempt to model interaction, especially in public-facing multi-user settings. These problems sit more in the complex category and therefore need a different approach to understanding how to build successful solutions.

The fluidity framework and the lean-observe build methodology are two contributions that are helpful in attempting to maximise the probability of successfully designing for multi-user tabletops. The degree to which the problem is dependent on certain contextual issues, such as the physical environment, the existing work practices, and the knowledge of users, can be understood by analysing the situation according to the technology complex. The more sensitive a given solution is to uncontrollable contextual factors, the more random the chances of success will be, therefore the more important it is to use a reflective, iterative, and ethno-design-led approach.

9.1 The Importance of Context

The subtle design decision and changes during the deployment in the two studies support the notion that multi-user tabletop applications are sensitive to context. Small, seemingly insignificant changes such as moving the position of a poster stand had observable consequences. This is in contrast to single-user systems, some of which are far less sensitive to context. That is to say that outside of the design decisions affecting the application logic and interface itself, little else has much of an impact. The wider context of social factors, environmental factors, space around the device, the presentation of the device and placement of associated paraphernalia (signs, printers, chairs), is much more important in the case of these two studies.

This is shown in chapters 5 and 8, where the evaluation of the two tabletop systems developed in this course of study revealed how important contextual factors were in the success of these systems. Considering how users approach the tabletop from a cognitive and physical perspective, in the case of CamPlan, allowed us to make design decisions that were impactful. The inclusion of appropriate representation on the signage, the inclusion of an attract/instructional video, the just-in-time contextual help, all contributed to the successful orchestration of the interaction.

9.1.1 Contextual Factors affecting Tabletop Design

Dey and Abowd (2000) proposed that explicitly considering all factors that can affect a system allows the designer to better adapt a system interface by adjusting it to the user's task through implicitly sensing contextual information. Dourish (2004) responds to this by saying that simply enumerating all possible

contextual factors cannot express how a system will work in reality, taking into account that the system itself changes the context. Although both sides have merit, I began my exploration of the problem space of designing for multi-user tabletop applications by considering the important factors. This afforded me the opportunity to understand the boundaries of various important factors, considering them individually, and to organise research by these themes.

As mentioned in the literature review, Wallace & Scott (2008) suggested that considering context is important for successful design of tabletop systems. They put forward five important contextual factors derived from who, what, when, where, why questions. In understanding the important factors related to the tabletop systems reviewed in both the literature review of this dissertation, and the two studies conducted, I have created a lightweight framework, with the acronym IDEAS (standing for Interface, Devices, Environment, Application, and Social), to serve as a more focused 'checklist' of factors to consider than the 5 'W' questions, with a greater alignment to my personal experience conducting this course of research.

9.1.2 The IDEAS Framework

The five factors mentioned above are inter-related and should be considered holistically. They include several of the components of the Technology Complex (Fleck & Howells, 2001), focusing on those components that are most pertinent to tabletop systems and co-located collaborative tasks. Although the IDEAS framework is not sufficient to ensure the success of a system, it can be taken as a starting point for addressing novel multi-user systems.

9.1.2.1 Interface

In many cases, the interface is what the designer of a software application will be seeking to create. Consideration of the other four factors of IDEAS should have an impact on their choice of interface. The interface should communicate the affordances of the application, as well as communicate the current state of the system with respect to the users' progress through the application flow. The metaphors of the interface can be considered, such as whether or not to mimic existing table-based objects, such as cards or stacks of paper.

As mentioned previously, reports in the literature of attempts to port interfaces from traditional PCs directly to tabletops have typically not been successful. The differences in input method and orientation alone are enough to warrant a complete re-evaluation of the methods of communication between the technology and the user, even in a single-user scenario. With multiple users it becomes even more important to consider the orientation and location of on-screen elements and how these can influence collaborative work styles and communication, as well as cultural cues and social awkwardness.

The potential for confusion following an interruption, and the need in a co-located collaborative task for users to switch between work 'inside' the interface and communication 'outside' the interface, mean that providing meaningful visual cues as to the state of the system are crucial to allow users to recover from interruptions, distractions and errors.

As well as accommodating the obvious input limitations such as finger size, it is important to reduce clutter (Guimbretière, 2002) and traditional visual

'chrome' from on-screen elements to adapt to the direct manipulation metaphors of touch-screen interfaces.

9.1.2.2 Devices

Consider the physical qualities of the devices in the system, as well as their culturally-based expected uses. If there are multiple devices, such as individual phones and a shared tabletop, how will these devices interconnect and share data? Each device has a certain form that makes it more suitable for certain tasks and scenarios than others. For example, when a user is waiting at a bus stop, they are more likely to take out their phone to check a timetable than to read about the history of London buses.

Similarly, a tabletop has a certain set of physical affordances which make it appropriate for tasks involving two or more people. The flexibility in configuration of users around a tabletop, the ability to rest and move objects across its surface, the large area which allows for flexible configuration of territories for personal and shared work, or public and private media.

9.1.2.3 Environment

"There is a drive to make the interface "disappear" (Weiser) and to take advantage of the computational abilities whilst retaining the flexibility and social adaptedness of existing tools for collaboration such as furniture and pen and paper. This embodies a shift from seeing the environment and its' objects as containers or pedestals for computing to a view of furniture as communication vectors. This not only affects the objects but also what happens among and between them. There is a two-way effect between the objects, the task, the users and the environment."

A tabletop is a significant object in a room. It suggests the type of work that can be performed at it, and the ways in which people can sit or stand around it. This causes interplay between the tabletop and the surrounding space. Its position can suggest intended modes of use, such as in HealthTable, where placing it against a wall with two chairs on one edge lets users know important information about how it should be used before even seeing the interface.

The choice of situated space will imply the context of use as well as the nature of interaction that is appropriate. For example, a tabletop in a museum will be suited to an interactive application related to the exhibit, whereas this would not be appropriate in a hospital. Similarly, the nature of the interaction will be more casual and the users will have different expectations about the range and detail of the application and its content.

9.1.2.4 Application

The choice of which tasks to support should be informed by a careful ethnographic-style study. Understanding existing organisational and social processes will help in being able to target a particular real-world need. Once chosen, it is recommended that the support of this task should be contained to as small a scope as possible. For the reasons stated elsewhere in this dissertation, when choosing to support a multi-user task, especially in a public space, the demands on attention, sources of distraction, and social effects such as not wishing to appear incompetent, it is important to make the application as easy to learn as possible, and easy to understand what its purpose is.

This is different from a single-user application where there exists the ability to extend the functionality of an application as the user's experience grows. The popularity of 'apps' on smartphones and tablets can be interpreted as a signal that, especially in casual use cases, users wish to 'configure' their devices to perform singular tasks. Like Heidegger's hammer, when a user reaches into their pocket to take out their phone, they have already chosen which task they want to perform (and which led to them taking out their phone voluntarily). Understanding the users' motivations for engaging with a certain technology, and their purpose with relation to a certain goal, will help in choosing the scope of the application the tabletop should support.

9.1.2.5 Social

The social factor of the framework includes both the cultural context and the dimensions of the intended user population. Group size, familiarity with technology (especially touch-screen devices), familiarity with each other (friends vs. strangers), the emotional context (e.g. a hospital vs. a hotel lobby), and many other factors can affect the nature of the interactions amongst the group members, both inside and outside the interface.

As mentioned in Chapter 4, the notion of 'user' in a multi-user system, especially one intended for use by the public, is a challenging one. It may be possible to predict certain characteristics about the user population based on where the tabletop is situated, such as native language, or ethnicity, but in an open public space factors such as age, experience with technology, or group consistency and coherency, cannot be predicted. Clearly in some situations it will be possible to tailor the tabletop system to a specific target user population, and in this case it

behoves the designer to understand this population and their organisational context as well as possible.

9.1.3 Application of the Framework

Returning to Hinrichs and Carpendale's Vancouver Aquarium study, described in Chapter 3, we can explore the IDEAS framework by analysing this deployment in a systematic fashion. The Device used here is a pair of FTIR multitouch tabletops. This leads to the research question of how users engage with the form factor such as how they approach it and how its size affords various types of activity, such as over-the-shoulder or at-a-distance learning, and simultaneous multi-user interaction. The Environment here is the Aquarium. This is a public space where many demographics of user will be encountered and very little can be said about their computer-literacy or previous experience with similar devices or applications. However, having chosen to attend an aquarium we may assume that they are already in a mood which is conducive to learning and exploration.

The Applications are primarily concerned with exploring information, in a more or less structured fashion. This leads to the research question of how do users choose to interact with this information. What styles of interaction, information seeking and collaboration do they spontaneously use (there was no external guidance on how to use the tabletops)? The Social factor here largely concerns the user population (museum visitors) who, as mentioned, are somewhat self-selecting in that by attending the aquarium they have already made an effort and a commitment to spend some time there. There may also be a large proportion of families, i.e. children and adult groups. How will children and

adults experience the tabletop differently? Will adults use the tabletop differently if interacting alone or with children?

The Interface will therefore have to reflect the various factors outlined above. As mentioned elsewhere, the quality of the content is important in order to give confidence to potential users that the system is worth spending time with, and to keep them engaged once they have started.

9.2 The Lean-Observe-Build Methodology

A key factor in the creation of the two studies was a fast development process, which allowed for changes in the system to be made as issues emerged, to try out new ideas quickly as observations of the system in use led to their formation. Microsoft researchers have written about the RITE approach in respect to the creation of games (Medlock *et al.*, 2002). In this approach, problems which are uncovered in regular user testing are worked on and fixed immediately during the software development cycle, rather than being catalogued for fixing in a later release. The LOB approach employed in this course of work differs from this concept by including feedback in all stages of design, development, and deployment, and allowing for changes in core design elements which reflect an awareness of the situated context, rather than simply a quality assurance measure.

In both studies it was important to start developing ideas in lower-fidelity forms before starting to concretise any effort. Choosing the appropriate levels of fidelity when developing ideas and gathering feedback allows for exploration of more problems and solutions quickly. For these studies, the first format for exploring ideas was sketches on scraps of paper. Working quickly and visually

gives the designer something to react to, and allows various forms of external cognition, visual recombination, and mixing of media to occur. Again, this applies especially to problems which exist in the 'complex' Cynefin category.

When designing for CamPlan, as opposed to HealthTable, we had to make assumptions about the goals of the visitors to the information centre. Although this was informed by extended ethnography and interviews with assistants, it was not possible to say for certain what the goal of every person passing through the centre's doors would be. Furthermore, there was no one who could say with certainty what the effect of the tabletop intervention would be. The ability to observe people using a live application allowed us to infer what their goals were by observing how they used it, and hopefully their apparent satisfaction. At times, users who came in with goals other than making a group plan for a day would creatively reappropriate the tabletop to better support their immediate goals.

9.2.1 Challenges

One of the main challenges found was that the Lean Observe-Build approach requires the designer to be poly-skilled. In creating the two prototypes I had to serve as ethnographer, designer, builder, programmer, and evaluator. When I realized that my skill as a programmer was becoming a blocking issue for the CamPlan study, I recruited a programmer, Stefan. This meant we had to discard the existing work on the code base which was done in C# so that Stefan could start writing in the language he was more familiar with—Processing. We soon caught up and the additional speed and flexibility made up for the several weeks of lost coding time.

This also served as a valuable learning: namely that using tools which let you think and build quickly is more valuable than using the ‘right’ tools, or those that yield the highest quality (the rendering resolution of the CamPlan application was lower for the change in programming language, for example). However, as the designer I had to pair closely with Stefan to guide the development process, as he had been absent during the ethnography and design stages.

The process of developing CamPlan was intensive, and taking a Lean Observe-Build approach meant that it was quite demanding in terms of resources and concurrent manpower. This could be an issue for the adoption of this approach. However, the process was also quite short, in terms of time. It did require many members of the team to be multi-skilled and able to work flexibly with demands which changed often in the course of a single day.

In the case of HealthTable, the main issue was having sufficient access to the space and to experts who could inform the design and provide feedback. This was due to the special nature of the studied location—the ER ward—and in retrospect it might have served us better to choose a less busy environment, such as a physician’s office, or a different situation, such as patient education ahead of surgery.

9.3 Key Discriminators in Choosing Tabletop Systems and Design Criteria for Tabletops

In creating tabletop applications for in-the-wild settings, it is important to be able to continue to refine a design *in situ* and to be prepared for surprising

findings and being open to changing fundamental aspects of the application as users are observed and the truly valuable opportunities are uncovered.

In order to deploy in a public space, the hardware chosen was off the shelf, since building custom hardware would have been a very costly option and the hardware had to be robust and reliable. With novel technologies such as tabletops, software development frameworks are much less mature than, for example, web design. The existing toolkits did not assist greatly in making rapid prototypes. This underlines the importance of conducting research such as these studies, as the existing software development toolkits were developed for imagined uses that are quite limited, such as photo sorting. To date, tabletops have been used as a technology to support various collocated activities, including games and photo sorting (Rogers *et al.*, 2006), but truly valuable applications of the technology seem to be several years away.

In choosing which problem areas to consider for the two studies, I tried to be as methodical as possible. Using McGrath's Task Circumplex (1984) was helpful to a degree, but it took a period of time spent simply drawing and imagining creative uses of tabletop technologies to find a concrete need and use case which was not only valuable but would include elements which would be valuable in terms of learning more about tabletop interaction.

It is not possible to simply transfer single-user applications from PC to the tabletop and expect them to be successful. The difference in input method, the problems of coordinating multiple users, issues of orientation, text input, and personal and shared space are too influential in the success of a design.

One of the stated research objectives in this dissertation was to understand what problems tabletop interventions are suited to. The experience gained in this course of research has led to key discriminators which include the following:

- An application which does not require a lot of text input
 - Text input is cumbersome on tabletops and can lead to frustration. This finding is supported by Ryall *et al.* (2006) who found that “tasks such as the organization, examination, or annotation of digital media are better suited to co-located tabletop collaboration than text-entry tasks.” Text entry was also found problematic in a lab-based study conducted in this course of research. The problem is greater in public settings, where any text entry is problematic, on tabletops or other technologies. Hinrichs *et al.* (2007) provide a review of text input methods and found it to be problematic.
- A simple application which allows for robust interaction
 - Minimising the use of modal interfaces, allowing users to undo actions, supporting both individual and shared action. All these things are important, since increasing complexity of the application and its supporting interactions can be overwhelming when there is so much interaction happening outside of the interface.
- Support flexible coupling styles

- As Tang *et al.*'s (2006) work shows, and CamPlan supports, the natural form of collaboration around a tabletop tends to be dynamic. Implicitly support tightly- and loosely-coupled work, and fluid transitions between these. Allow for a broad range of socially-focused gestures (e.g. reorienting an on-screen object to another user can suggest that they should pay attention to it).
- Focus on activities which support the group's goals, rather than individual user persons
 - The concept of the 'user' is diluted in multi-user environments and hence should be defocused. This is especially true in public settings, where little can be known about the characteristics of the users, but even in know populations the demands of synchronous collaboration (conversation, managing interruptions, interference etc.) mean that the focus should be on communicating the status of completion of the flow in a robust fashion. This is except in the case of when one user has different knowledge or skills, e.g. a doctor, who can make use of specialised application flows which are separate (e.g. parallel or subsidiary) to the flows followed by other group members.
- In concert with the point above, it is best to keep the aims of the application and the interface as simple as possible.
 - The same way that the most successful mobile applications are single-focused, this makes it easier for the users to keep track of what they are doing, even with minimal attention and through

interruptions. If more features are needed, consider whether it is possible to put these in a distinct flow which can be operated at another time. Simplicity itself is relative to the users' skills and sensitive to context. It can depend on the user's motivation, prior experience or training, the level of control they have over the wider interaction and the support or distraction of people or artefacts in the immediate environment.

- Given the importance of the first few interactions with a new application in helping motivate the user and build confidence in their skills, using existing known gestures, interface elements, and real-world elements can help to accelerate learning.
 - Modelling physical behaviours such as inertia and elasticity, as in Reality-Based Interfaces (Jacob *et al.*, 2008), helps the user natively understand the properties of objects on screen. Hilleges *et al.*, (2007) refer to this as 'pseudo-physicality,' and suggest that making on-screen objects behave like their physical counterparts can result in a more simple and intuitive interface.

These discriminators are not intended to be absolute: rather they are meant to serve as a condensed set of criteria that are worthy of consideration by any future tabletop system designers, based on the experience gained in this course of research.

9.4 Findings from HealthTable

One of the main issues with the HealthTable study was access to the medical professionals. Doctors were wary of technology, having seen so many hi-tech solutions that were supposed to make their lives easier come and go. There was also a high degree of politics and bureaucracy that I needed help with in obtaining and maintaining access. Doctors were short on spare time and did not seem willing to invest energy and time learning a new tool, or to risk the possibility of looking foolish in front of a patient or other doctors.

One of the reasons for the choice of second study was to move towards a more available target population, namely the public.

9.4.1 User Symmetry: Doctors and Patients

One of the interesting findings for tabletops is that they can lead to more equitable interaction. In a dyad such as doctor-patient, the interaction is skewed in several ways. Physically, in the Emergency Room, the doctor has physical access to the computers and screens. Socially, the doctor is visibly distinct to the patient, and has access to a vocabulary which can exclude the patient.

Guided by research which pointed to failures in patient education being a real and important problem in medical care, the position was taken that one of the factor that could be altered by introducing the tabletop was to 'flatten' the interaction. That is to say, to reduce the difference between doctor and patient along these physical and social lines.

The choice to use two chairs side-by-side at the tabletop was intended to equalise the access to input and to allow a shared orientation. Also, the side-by-side placement is less confrontational than face-to-face.

Observation of a patient and doctor using the tabletop to deliver insight to the patient found that the patient did appear to have greater control over the interaction. Although one of the chairs was missing, the patient was seated and was able to control the pace of the description from the doctor using gestures and arm movements, which might have been impossible had the doctor been facing one of the high up screens on the nurses station to conduct his discharge. Given that, when interviewed, the patient said that the table, especially the interactive body model, helped her understand her condition, support was found for the symmetry concept and support for the application in assisting the patient education and 'flattening' the interaction.

9.4.2 Embodiment

A very interesting observation of the tabletop in use was the way in which the patient and doctor were able to conjure a connection between the on-screen representations and the patient's body. While discussing the position of the kidneys, the doctor and patient would move back and forth between the 3D model on screen and the patient's own body. It is hard to say for certain, but it is likely that this would have been less pronounced had the same process taken place at the nurses' station with both participants stood up and the doctor leading the interaction more dominantly.

One factor that might warrant further investigation is the effect that representing the information in a horizontal plane has. At the time of the study,

tablet computers did not exist in the form of the iPad, and consuming digital content horizontally was very unusual. I am not aware of any studies that look into the comprehension and retention of information, and other collaborative learning effects, of using digital screens horizontally as opposed to vertically. However, as mentioned above, it does appear from observations that the increased equitability of access afforded by the tabletop form factor allows the learner to have more control over the pace of the interaction and to raise questions more easily through gestures.

When it comes to sharing personal information on a shared surface, the patient is likely to feel confident in doing so with a medical professional. However, sharing personal information with others may cause problems, depending on the context. Hence, the territoriality, visibility, and access to information when viewing sensitive personal information needs to be considered when designing collaborative applications. It may be suitable to use a personal device such as an iPad to allow users to control the privacy of their information more tightly, and allow patients only to share what they wish to on a shared central surface.

9.5 Findings from CamPlan

9.5.1 The User Funnel

Taking Brignull & Rogers (2003) concepts of the thresholds of awareness and interaction, I have extended them to include the changes in role which can occur in multi-user settings, from observer to driver to master.

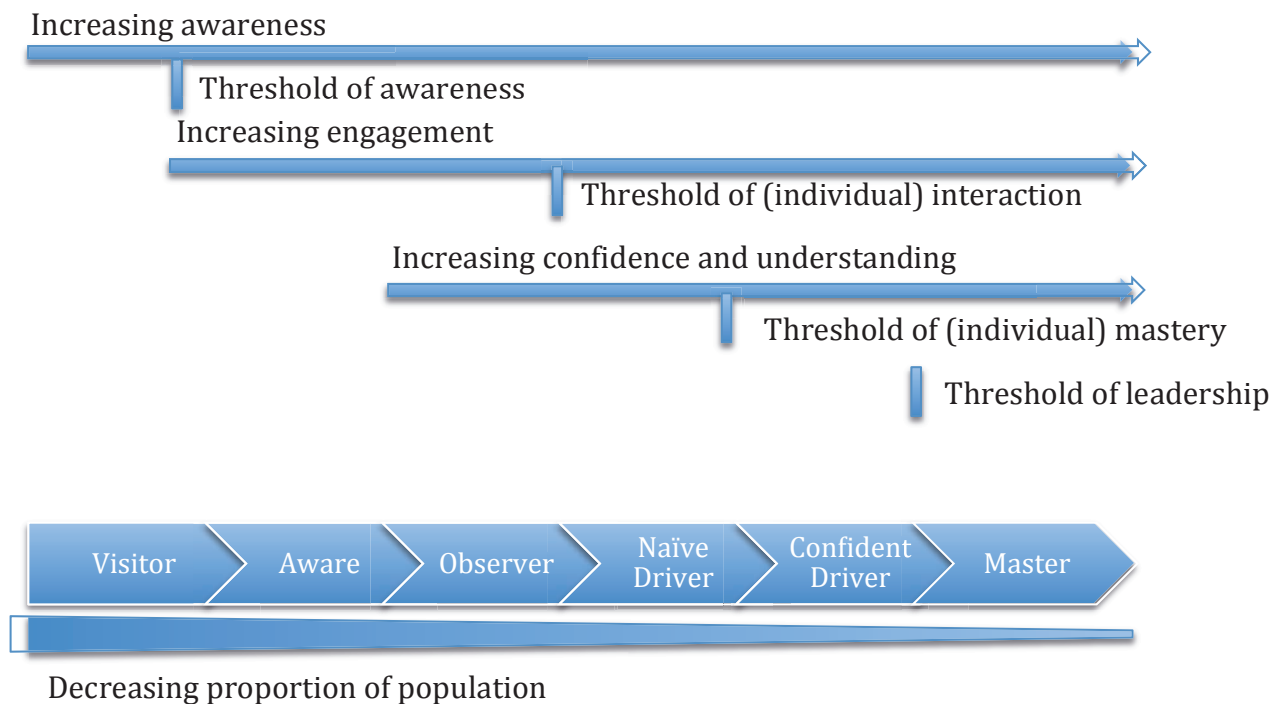


Figure 9.1: Illustration of the user funnel and corresponding thresholds.

It was interesting observing the ways in which visitors to the centre would watch people using the tabletop in an over-the-shoulder manner. If a visitor is seen being an observer they were much more likely to engage with the application themselves at a later point, either immediately when the current user leaves or after a period of time involved in some other activity. Observation of other users was a far stronger predictor of use than people watching the instructional video or reading the poster. This may be because the sight of someone using the system provides greater confidence for the new potential user, in terms of confidence in how to use the interface, the social acceptance, and the perception of value of the activity.

When one member of a group has started using the application and another member of the group comes over, they seemed to be approximately as likely to remain an observer or become a co-driver as to become a driver and start their

own session. Sometimes the new participant would take interest in what their group member is doing and make suggestions, becoming a co-driver. When they realise the limitations of having only one carousel, such as only having three available choices, and understand the possibility of starting their own session, they could then make the transition to become a driver in their own regard.

As a driver, their interactions may change slightly as their confidence grows. Initially they might be trepidatious, making small gestures, making small experiments in order to understand the interface better. As their confidence and understanding grows, and their mastery of the interaction builds, they may make larger gesture and begin to use the interface creatively. As their understanding of the group nature of the application grows, if other members of their join the activity, they may take an instructional role, and orchestrate the application in a more hands-off manner 'outside' the interface.

This user funnel effect is similar to Michelis & Müller's (2011) Audience Funnel effect, which was observed with interactive screens in a public space. They observed that the behaviour of their audience exhibited recurring patterns which seemingly represented awareness, then exploration from initially subtle interactions through to more complex direct interactions.

9.5.2 Coupling Styles

In their 2006 study, Tang *et al.* found that task properties that affected collaborative demands also influenced the proximity of collaborative work at a tabletop. They categorised seven pairing positions around the tabletop, from stood together to stood at opposite ends. They then modulated the collaborative demands of a map-based tabletop task. Collaborative tasks have been

conceptualized as being on a dimension from loosely- to tightly-coupled (e.g. Salvador *et al.*, 1996). Tightly coupled, generally speaking, means that the participants are interdependent on each other and cannot do much work before having to interact in some way. Loose coupling, conversely, is when participants are able to work for long periods without interacting (although still needing to combine efforts at some point).

Tang *et al.* found that the more tightly-coupled the interaction was, based on the demands of the collaborative task, the closer users would stand around the tabletop. Furthermore, they found that participants changed positioning quite naturally and with minimal discussion as the task changed.

This seems to match what was observed in CamPlan, where users would move to see each other's carousels, stand close to each other when working together and move back to their own side when working independently. It also applied more grandly to the modal change to the review screen. What Tang *et al.*'s work suggests is that this reorientation may not simply be due to the cues of orientation, as we assumed in the design phase, but may also reflect the tendency for users to position themselves closer for a more tightly-coupled tasks. In this case, the review screen meant that everyone had to reach an agreement about the plan for the day, the order of the cards, and whether to print.

9.5.3 Lowering the Thresholds

The fact that the tabletop is a novel device, and that the large glowing touchscreen invites use, lower the thresholds of attention and interaction. Increasing the proportion of visitors who cross these thresholds can be thought

of as either lowering the threshold by reducing the barriers to successful interaction, or increasing the potential users' motivation to cross these barriers (Fogg, 2009). Accordingly, the poster is serving to lower both thresholds by increasing the likelihood of the visitor becoming aware of the application and communicating its intended purpose. By showing the stages of the application, and a photo of a group stood around the tabletop and interacting with it, one can help to model the intended use in the mind of the user and increase their confidence in using the system. Describing the value to the user and to their group of going through the application hopefully increases the motivation of the user to start interacting and to persevere through frustrations.

Support for this notion is the uplift in usage we observed after making revisions to the poster and the positioning of the stand.

9.5.3.1 *Modelling Successful System Design through Motivation, Perceived Difficulty, and Perceived Value*

The greatest predictor of somebody performing an action is the intention to perform the action. When we wish for people to use our system we want them to decide that doing so is the best decision they can make in the moment.

According to Fogg's (2009) Behaviour Model for persuasive design, when presented with a stimulus such as the presence of the tabletop in the VIC, if the user is motivated enough and perceives the barrier of use as low enough then they are likely to intend to use it.

Once the user has made their first interaction, the designer of the application should endeavour to make their first experiences positive and to keep the users moving towards their goals with high fluidity. High fluidity in this case means

the ability to make direct manipulations in a cognitively 'effortless' manner whilst being able to think on a high level about the aims of their day out, manage multiple constraints, whilst simultaneously managing interaction and collaboration with other members of their group.

Once a member of a group is engaged with the application, it is not as important to convince each following member of the group through the same means. At this point, it is important for the user to be able to demonstrate what they are doing easily to their friends and to make it easy for other people to join in, whatever stage the other user is in (asynchronous joining).

It is always important to strive to make casual interactions such as these as surprising and delightful as possible, but even more so when part of the success of the system lies in getting the early adopter to evangelise to other members of their group. Their enthusiasm will become infectious and motivate others to join.

The motivation to use a tabletop system may be affected by personality factors of the user. Perhaps a more introverted personality would be keen to use an automated system rather than talk to an assistant, especially if they are exploring rather than with a specific question in mind. Will 'early adopters' and technophiles be more likely to use the system regardless of its appropriateness for the goals they came to the VIC with? Will 'late adopters' be convinced of the value of using the system or feel that it is easier to use than the alternatives (e.g. the kiosks)? More research is required to understand how users' experience and attitudes towards technology affect this.

9.5.4 User Symmetry: Adults and Children

As in HealthTable, we considered the ways in which the individuals in the group of users could differ. For example, a parent and child have asymmetry in various ways (e.g. size, authority, finances), whereas a pair of teenagers are roughly symmetrical along these factors.

The inclusion of the step at the side of the table was intended to reduce the asymmetry in one critical dimension: young children were better able to reach the screen, and did make use of the step. Compared to other ways of contributing to the plan for the day, the tabletop allowed for greater equitability in amount of contribution for children vs. adults.

The greater the asymmetry between users, for example in experience using similar devices, the more verbal and physical instruction took place, with more confident and experienced users providing instruction and leadership for the application. Greater asymmetry led to more discussion about the activity as well as discussion about the interface and the technology itself.

9.5.5 Interaction Similarity Confusion

Especially on the CamPlan study, users were observed attempting gestures which are performed on touchscreen phones and tablets. These included tapping objects to change modes and pinching to zoom. It is therefore important to consider whether gestures already understood by the majority of users can be re-appropriated for a tabletop application, or to provide feedback in a helpful way, such as allowing zooming or scrolling, but snapping back to indicate that although the gesture was recognised it does not perform any function in this application.

In particular, people were observed double-tapping on the cards on CamPlan, which initially was not a supported action. Upon observing this, changes were made that meant double-tapping on a card that is in the carousel caused it to animate out. However, the interface itself has to support and scaffold the user so they can easily learn how the interaction differs due to the differences in physical space and the presence of other users.

9.5.6 Positive Effects

Discussion about the activity of choosing attractions as it was happening seemed to occur and we can hypothesise that this led to positive effects for planning. For example, when one user says “you don’t need to add King’s College, I’ve already got it. Put in the market card ‘cos I want to see it” we can assume that the other person has an awareness about that person’s preferences for which attractions to visit. The user is talking about the constraints of the system, but is also perhaps forced to consider the constraints of time that it reflects.

Part of the appeal of the tabletop was in how it differed from the other sources of information in the VIC. It had little clutter and was easy to navigate, was accessible in terms of height, and provided printing and side-by-side comparison of attractions, as well as time calculations, maps etc. which were not offered by the kiosks, as well as being conducive to collaborative planning. The appeal of it as a ‘cool’ device is supported by the fact that a local TV station decided to cover it in the evening news.

Another important factor was the ‘halo effect’ of the experience. Positive interactions are likely to leave users with a positive impression of the whole

VIC. Evidence that the experience was positive is given by the fact that a large proportion of users paid after printing, many paying over the suggested amount.

The colourful and fun design was intended to make the interface look 'permissible' and not appear as though it is only for official use. Compare this to an example where interactive screens in shoe retailer appeared as though for use only by staff which led to customers not engaging with the system (personal communication with Y. Rogers, 2013). That example also serves to underline the importance of paying attention to context. In this case, the application was to design and customise your own shoe. This was based on a system already available on the manufacturer's website. However, due to the change in context (i.e. the setting, the interaction method) simply porting the existing application to a touch screen in store was not successful.

In most cases with CamPlan, groups formed at the table composed of people who were already part of a coherent group before they entered the VIC (although not as many of these were 'families of four' as presumed in the early design stages). However, in some cases people who were not related came to use the tabletop together at the same time. The result of this was frequently confusion, due very likely to the fact that at least one of the users did not know that the system was intended for group use and, for example, that going to the review screen would require everyone to agree. Happily, there was one case of some young women who were using the system who, when this happened, struck up a conversation and ended up agreeing to spend the day exploring the city together. This does raise the idea of how we could design for producing this more favourable result over mere confusion.

As noted by Inkpen *et al.* (2004) the positive effects of collaborative interaction can be subtle, and it is important not only to focus on the outcomes of the activity, but also how the manner of the interaction is modulated. In the case of CamPlan, does the fact that a family made a plan collaboratively, including the children's opinions, produce further effects not observed, despite potentially having the same outcome? Will decisions about what to see be affected later on in the day once the group have left the centre? Will the fact that everyone in the group has been involved lead to greater equality in knowledge and easier decision-making? Does an increase in the number of alternatives considered during planning make later decision-making and adjustments easier? Does the sense of enjoyment go up because members of the group all feel they have invested and been included in the decision? Further work is required to assess how the tabletop intervention may have other downstream effects.

9.5.7 Challenges

We found that far fewer families entered the VIC and used the tabletop than we had expected. This may be due to the different time of year from the period of ethnography to the carrying out of the deployment. Instead, we found a greater mix of groups including tourists and school groups. The ways in which users approached the table meant that members of a group tended to arrive at the table 'buffet' style, rather than 'dinner' style, which is to say, at various intervals rather than all sitting down at the same time to being simultaneously.

Lab studies on group tabletop tasks have tended to take the latter form and pre-suppose that groups will arrive and begin at the same time and with the same context in mind. This proved not to be the case, and is an example of how in-the-

wild studies reveal deep insights about the nature of tabletop studies, which are missed in the more artificial lab setting.

One alternative design would be to constrain the interaction in order to ensure more conformity with start of the group's interaction. This might also avoid the problems of collisions which occurred when individuals who did not know each other tried to use the tabletop at the same time. However, this would mean that the 'evangelism' component of the first group members recruiting their other members, and would be likely to reduce the overall number of sessions.

10 Conclusions and Future Work

The motivation for this research was to explore real-world use of tabletops, specifically in settings that are chosen for their suitability for this form of technology intervention based on activity characteristics. Although numerous studies have focused on issues such as interface design, gesture recognition etc., a critical factor for adoption of these devices is to understand the motivation and barriers to designing and deploying successful solutions.

In this thesis I described a problem context of designing applications for multiple users with tabletop devices. I then conducted a review of the literature, and found in-the-wild studies to be lacking. I also reviewed potential applications for study using tabletops. I then conducted further review of existing in-the-wild studies.

Next, I described some frameworks which emerged from thinking about the problem. These frameworks informed the design of two in-the-wild studies, taken from idea, through design and execution, to deployment and analysis. I then outlined a discussion of these studies.

Several factors are found to be important, chief amongst which employing an iterative and reflective approach to gathering requirements, designing, and building applications, conducting these as much as possible in the intended space. Also important is considering how a real-world need can be supported through tabletop-mediated activities, and this requires a focus on selecting only the most appropriate activities to support and designing an interface which communicates this as clearly and succinctly as possible.

As noted by Hilleges *et al.* (2007), with one of the most common activities conducted at a traditional table–brainstorming with pen and paper–digital tabletops made little difference in the number or quality of ideas produced with only limited extra value coming from the ability to store and retrieve work owing to its digital form. In choosing to employ a technological intervention such as a tabletop, even with a sensitively designed system such as Hilleges *et al.*, the cost and benefit of the system must be evaluated critically.

In the two studies conducted for this course of research, the digital tabletop extended what was possible with the existing tools and processes, such as generating a map and calculating overall plan times with CamPlan, or viewing digital medical media and instructional tools in a shared workspace with HealthTable. These benefits had to be communicated clearly and the progress towards the users' goals had to be expressed unambiguously.

Understanding of these key elements is hoped to be revealing to future designers and allow them to effectively design systems that can assist collaborative work. Generally speaking, this course of research started with a technology in need of an application. By exploring the problem space through the literature, through creative experimentation, and action research, this course of work revealed more general principles of design and frameworks and heuristics, which it is hoped can apply to other forms of multi-user technologies.

Conducting the two studies allowed the exploration through active participation in two different contexts. At least in regard to the Lean Observe-Build approach, action research seems to be the most natural approach to evaluating it, despite the difficulties of remaining objective. Findings from both studies are valuable

with regard to knowing better how to approach similar problems in the future. For example, with HealthTable access was an issue. Determining the needs and availability of the target population is clearly important in order to gather rapid feedback. With CamPlan, changes in target population and a considerable length of time to conduct design activities, testing, and *in situ* evaluation benefitted the success of the overall design. One significant issue in this study was the intended quality of the application and the coding complexity required which meant pairing with a developer. The availability of skills and resources for developing and conducting the evaluation also need to be considered therefore, as being lean in the design approach requires close pairing and effective communication.

‘Getting out of the building’ was a central theme to this thesis. In reaction to the lack of in-the-wild research on tabletop technologies, we sought to design tabletop applications that could provide concrete benefit for two types of collaborative activities. The importance of getting out of the building (i.e. into the target environment) and gathering feedback was found to be important in more ways than these prototype applications. If the challenges of working quickly, tightly-coupled, and reflectively on designing, building, and iterating on solutions can be met, then in cases where the problem exists in a ‘complex’ space, the chances of success are much greater in a Lean Observe-Build approach as opposed to trying to capture a snapshot of a system, codify and model it, and build a solution in a ‘one-shot’ or ‘waterfall’ manner.

Success factors were different for CamPlan, as a public walk-up-and-use system, compared to HealthTable. The need to capture attention and communicate value effectively was critical. The importance of the honey pot effect was noted,

and hence the importance of creating an enticing interaction that is rewarding in early use, and effective signage, is critical to maintain the chain of users. The application also had to conform to the expectations of the users and align with their goals, since visits to the VIC were normally quite short and not typically seen as an opportunity for prolonged experimentation with technology.

The designer of tabletop applications has to consider not only the human-computer interactions, but also the human-human interactions. They must make use of the means available to them to influence how the collaboration 'outside' the interface occurs to help facilitate the group towards to their goal.

The fluidity framework is intended to serve as a design lens, bringing the tabletop designer's attention to the manner in which their interface can support reflective, high-level thinking for the users, allowing flexible collaboration, good interaction, and lower working memory load and frustration.

The IDEAS framework is intended as a series of triggers to help the designer consider the various aspects of their design from multiple perspectives, and how their technological intervention might affect the wider systems in place, and what factors will be most important for a successful design. For example, in CamPlan, a tabletop application was developed to support group planning in a tourist information centre. This was compared to kiosks that provided information about the city. The environment (the tourist office) and the social aspect (groups of tourists) were the same but the device was different (tabletop vs. vertical PC kiosk) and the application was, through ethnographic research, designed to better support planning (whereas the kiosk only displayed a static website with information). The change of device meant that a group could use

the interface simultaneously and the application was made to encourage collaboration.

10.1 What is a User?

One of the deepest findings of this course of research was uncovering the need to explore the different nature of the concept of users in a multi-user system. This affects many aspects of this technology, from the need for a sensitive understanding of various contextual factors before designing, to the need for new design approaches which go beyond the single user methods such as user personas.

Users were found to behave in broadly repeatable patterns in the CamPlan study, which echoes the findings of studies of public technology from Brignull & Rogers (2003) and Michelis & Müller (2011). Findings from the CamPlan evaluation revealed a 'user funnel' effect that describes a pattern of behaviours that users of the system tended to go through, with decreasing numbers of people making it through consecutive stages.

Further work is required to explore this important factor of the nature of users and to understand how interaction between collaborative task, public setting, cultural and organisational expectations and processes, and different user populations.

10.2 Future Work

By using the techniques outlined in this thesis, the development of the prototypes employed in the two studies reveals the usefulness of these methods and validates them as appropriate tools for design of multi-user tabletop

systems. It is hoped that the findings of this course of research will go towards enhancing the tools and concepts at the designer's disposal for creating successful multi-user tabletop systems and a means of evaluating their effectiveness.

Naturally, since this study began technology has moved on and there are new classes of device that bring new opportunities and challenges. It would be interesting to consider how we could design for both problem contexts using, say iPads, or the new generation of Surface (now rebranded as PixelSense to avoid confusion with Microsoft tablet computers), and how this might alter the design decisions and the success of these technology interventions.

Does the acceptance of iPads and other consumer tablets change the way people approach public touchscreen technologies? Will the expanded set of interactions and gestures in the public consciousness lead to better adoption of public devices? Will the familiarity of using touchscreen tablets in domestic settings mean that members of the public are more willing to approach and use public devices such as interactive tabletops, or will the lower novelty hurt adoption rates?

It would be valuable to take the CamPlan system further and attempt to solve the problems of how to handle the situation that occurs when two or more people who are not from the same group start to use the application at the same time. Is it possible to effectively and productively either handle this parallel work, transition from individual to shared work, or communicate that this is not possible?

The settings chosen for the two studies shared in common one factor, which was that the user population were not in a position to spend much time with the tabletop. The effect of time pressure on the ways in which users appropriate tabletop technology might be a fruitful avenue for further research. For example, moving the HealthTable application to a less stressful environment, such as a doctor's consultation room, or translating the CamPlan application to a hotel lobby in Cambridge. Would different patterns of use emerge?

Several other potential applications were explored before choosing the two studies in this course of research. Collaborative video analysis, annotation, and statistical exploration between a sports professional and a coach would provide an interesting use case for a longitudinal use of a tabletop. This would provide an opportunity to discover whether the use of the tabletop changes over time with the same users. Collaborative data exploration, combining the graphical and computational power of the tabletop with the rich manual interaction and pattern-matching capability of the human visual cortex, would be a novel approach to the emerging issue of how to effectively use the 'big data' sets which are being captured. Does collaborative tabletop-based exploration yield a greater number and quality of insights into the data than other methods?

Is a tabletop system an effective tool for community planning, such as in a town hall setting, or for planning new air corridors for flights over populated areas?

Can a tabletop effectively support disaster planning, such as when environmental, police, fire, and government representatives go through disaster preparedness drills?

The methodological approaches of this thesis could benefit from further evaluation with a greater range of technologies, settings, collaborative tasks and use cases. The conceptual frameworks could be refined, operationalized, and validated further by applying them to both new systems being created, and existing systems.

10.3 Final Conclusions

To briefly recount the characteristics of tabletop systems, they are a type of large interactive touch-screen with a horizontal orientation intended for use by two or more people. It has been suggested that they are potentially beneficial in supporting co-located collaborative tasks by providing a shared workspace for manipulating digital objects.

This thesis has focused on issues relating to the design and evaluation of tabletop systems, has contributed to a greater understanding of this problem space, and has proposed methodological and conceptual contributions for maximising system utilisation outcomes. These were developed through, and applied to, two in-the-wild studies, which are reported in detail. A core conceptual contribution is the Lean Observe-Build approach, which is an iterative, reflective approach to holistic design and development. The need for a new design approach for tabletop systems arises from the dense forms of collaboration which occur in co-located tasks, and the sensitivity to contextual factors surrounding the use of tabletop interventions.

Conceptual contributions include the Fluidity Framework, which draws together a heuristic for evaluating the 'fluidity' of software and a conceptual lens for considering interface design alternatives. Terms such as 'goal,' 'activity,'

and 'user' are discussed in relation to the specific context of multi-user in-the-wild collaborative tabletop systems, and the IDEAS framework and key discriminators are provided to serve as a scaffold for considering varying perspectives on tabletop system design.

The first study reported took place in the context of a Emergency Room ward in a hospital and the application sought to improve medical care outcomes related to patients' understanding of diagnoses and treatment plans through supporting a collaborative learning activity. An iterative approach to exploring design solutions was followed and the application was evaluated *in situ* with a patient and doctor. Factors such as the asymmetry of the interaction and the ways in which the tabletop interface could reduce this were discussed, and support was found for the application succeeding in its aim. Limitations on the access to the medical setting and hospital staff hampered the study. The following study concerned a different user group and collaborative task.

The second study took place in the Cambridge Visitor Information Centre in Cambridge, UK. As an in-the-wild context this provided a large number of potential users. Initial ethnographies conducted in the VIC revealed that pre-formed groups came to the centre in order to plan their time as visitors to the city. An application was prototyped, iterated, and developed to support the collaborative planning of visiting attractions by a pre-formed group. The system was tested through rounds of paper-based and interactive prototypes and developed and refined *in situ* in the VIC. Observations were carried out over 32 days and video analysis was performed.

Factors such as how signage proved important to the adoption of the system, interface issues that were corrected in place, and confusion which occurred when un-related users attempted to use the interface at the same time, were discussed. The application was found to effectively support a collaborative planning task, and effects such as the reorientation of users on cues such as text and graphic orientation were noted.

To conclude, the contributions of this thesis provide the beginnings of a framework or series of concepts for future tabletop researchers and systems designers, enabling them to better understand the important issues of this problem space and the interconnected factors of context, collaboration, interface design decisions, use and adoption of tabletop systems.

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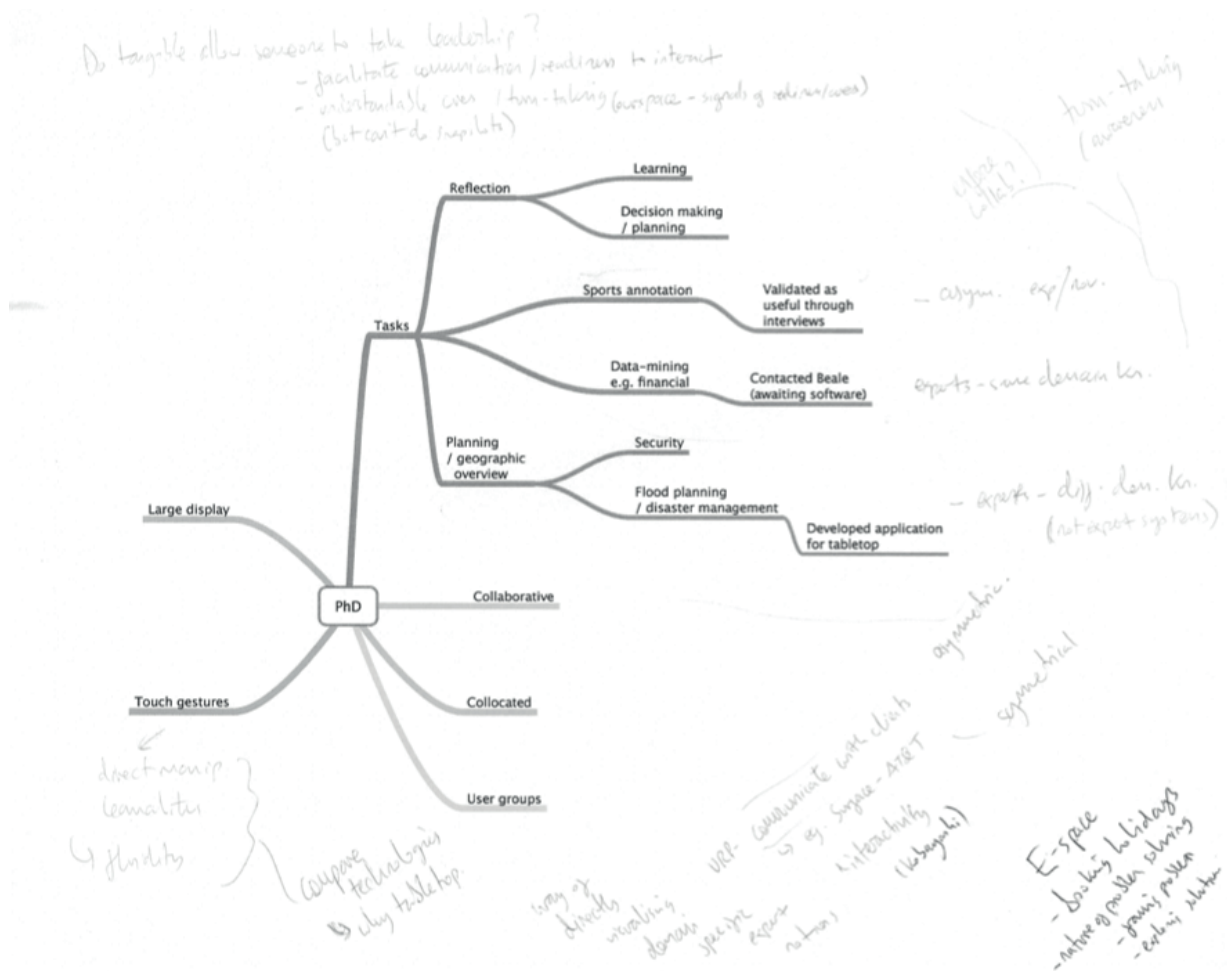
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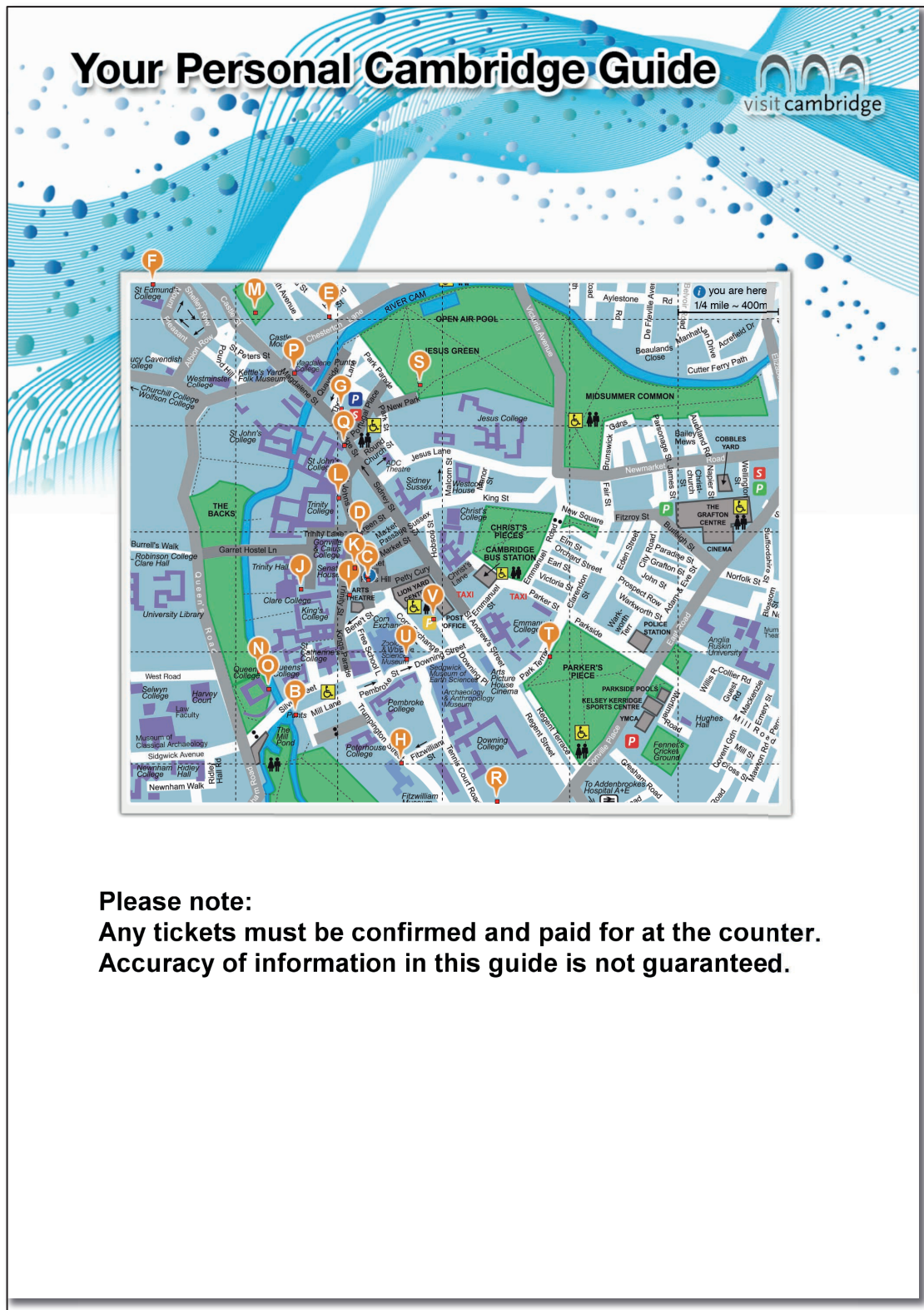
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12 Appendices

12.1 Tree Map of Potential Applications



12.2 Example Printed CamPlan Guide



A

♿
££



Guided Walking Tours

Walk around the most famous sights of Cambridge with a qualified guide to give you insights and information along the way. The tour lasts approximately 2 hours. Please purchase tickets at the information desk. Tours leave from outside the Tourist Information Centre.

Tour Times: 11am and 1pm/nPrice: 12 adult / 6 child / 11 conc.

B

♿
££



Chauffeur Punt Tours

"Experience punting in style and comfort while someone else does all the work. Relax as your guide takes you on a 45-minute tour along the River Cam taking in all of Cambridge University's riverside colleges. Includes King's College Chapel, the Bridge of Sighs, the Mathematical Bridge and the Wren Library. Tours depart regularly."

Daily from 10am to 6pm/nPrice: 12 adult / 6 child / 10 conc.

C

♿
£



Cambridge Revisited

"Situated right here in the Tourist Information Centre, Cambridge Revisited is a unique educational adventure. Visit the courts to see and learn about Cambridge and its Colleges. Witness the trial and punishment of those who have spoken the unthinkable – to mention 'the other place'."

Opening Hours: Mon–Fri 10am – 5.30pm, Sat 10am – 5pm, Sun 11am – 3pm/nPrice: 3.50 adult / 2.50 child / 3 conc.

D

♿
££



Bus Tour

"Enjoy the sights & sounds of Cambridge from the top deck of the hop on hop off bus tour. The audio commentary (available in 8 different languages) provides an informative and lighthearted history of Cambridge and its impressive University buildings. There are over 21 stops, both in & around the city where you can join the tour. The tour

Operating Hours: 10am – 6pm

E

♿
£



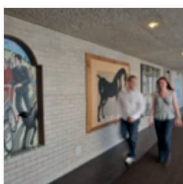
Folk Museum

"The Cambridge and County Folk Museum is one of the city's hidden treasures. Housed within a fascinating timber-framed building – formerly the White Horse Inn, dating from the 16th Century – the museum contains exhibits illustrating the work and everyday life of the people of Cambridge and its surrounding county. Closed on

Opening Hours: Tue–Sat 10.30am – 5pm, Sun 2pm – 5pm/n3.50 adult / 1 child / 2 conc.

F

♿
Free



New Hall Art Collection

"Contains nearly 350 contemporary works by women artists, including Maggi Hambling, Barbara Hepworth and Paula Rego."

Opening Hours: Mon–Sun 10am – 6pm

12.3 HealthTable Concepts





Microsoft®
ExecutiveCircle



Project Directives.

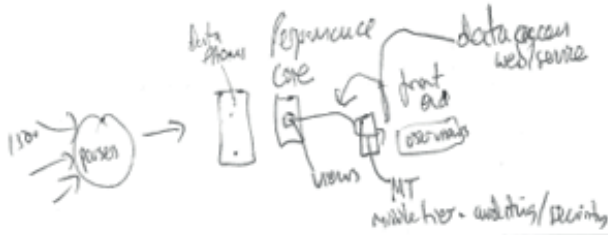
- △ Prototype - K&I deliverable.
- △ User study - ethno/time/natural/observation
- △ Final Report / Publication.

Health Vault API
↔ storage methods

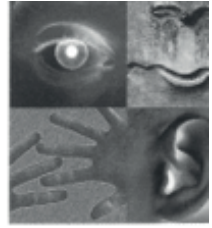
Data Centricity

Running web service stubs

Simple base view
→ de-identified data



Microsoft
Executive Circle



Surface - low res

- Low to slow Amalgam grid?
- J.G. LPF grid - exceed - customisable
→ torch wrappers.
- Doc sees just his patients?

- New SDK Surface - 256bit fiducials / relics

Shot changes - temp stacks
 session
 URL linking
 → bind to relic

Tangibles - doctors - lab reports

Patient Ed. ⇒ Krames - ed. resource.
 → how to access / organise?

Liz has
 → XML file of all Krames data.
 → interface / interaction

Collab. Task - report - previous intern. - ~~sent from~~ PD to send.

Patient - Patient - discussion.
 - Nurse - administ.
 - Doctor - consult. - Ed.

Alexi - folders

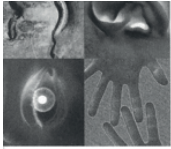
Doctor - Lab - waiting for lab results.

URL - Doctor has
 'current tasks' tag.
 pull.

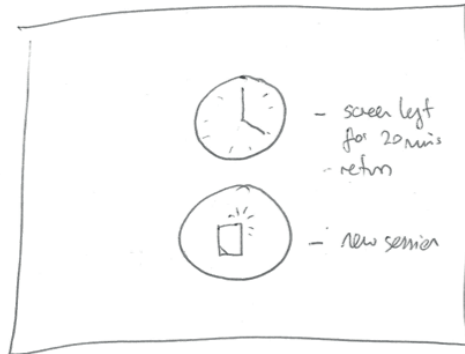
Nurse -

Renderers
 Framework runtime

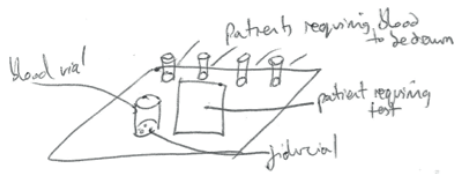
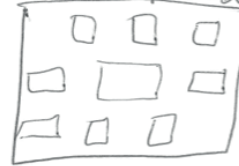
Microsoft
 ExecutiveCircle



Welcome to the Circle



overview
had
for organizing
rounds/
shift handovers



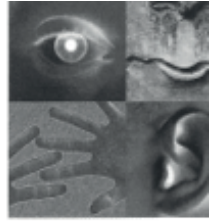
- preparing short/medium-term
tasks using tangible objects
central to the task

Microsoft
Executive Circle

- Auto-Generated

Discharge Component

Welcome to the Circle



- Signing - Ultrasonic per.

Chest X-rays - X-rays (high)
VQ scans (low)

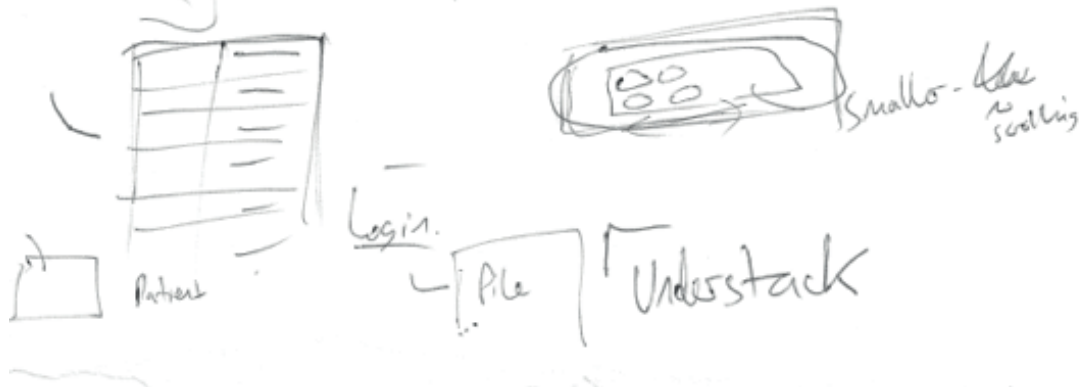
Image Stacks (CT's / MRI's) (high)

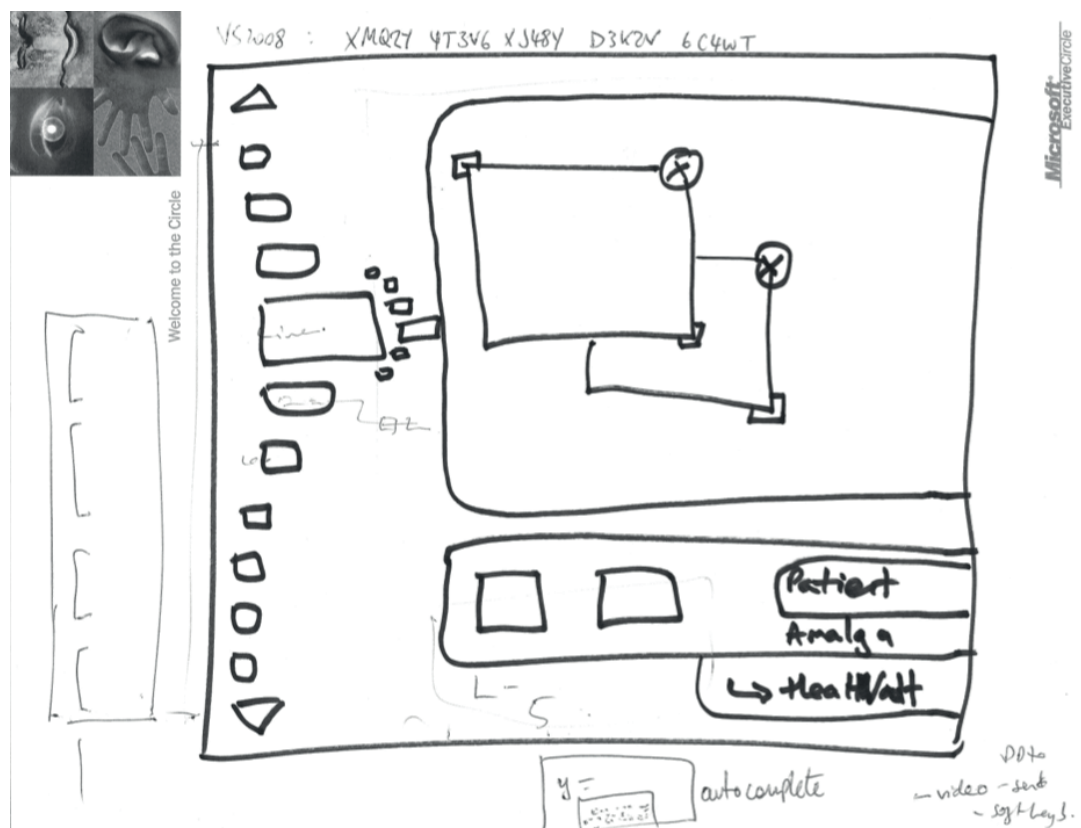
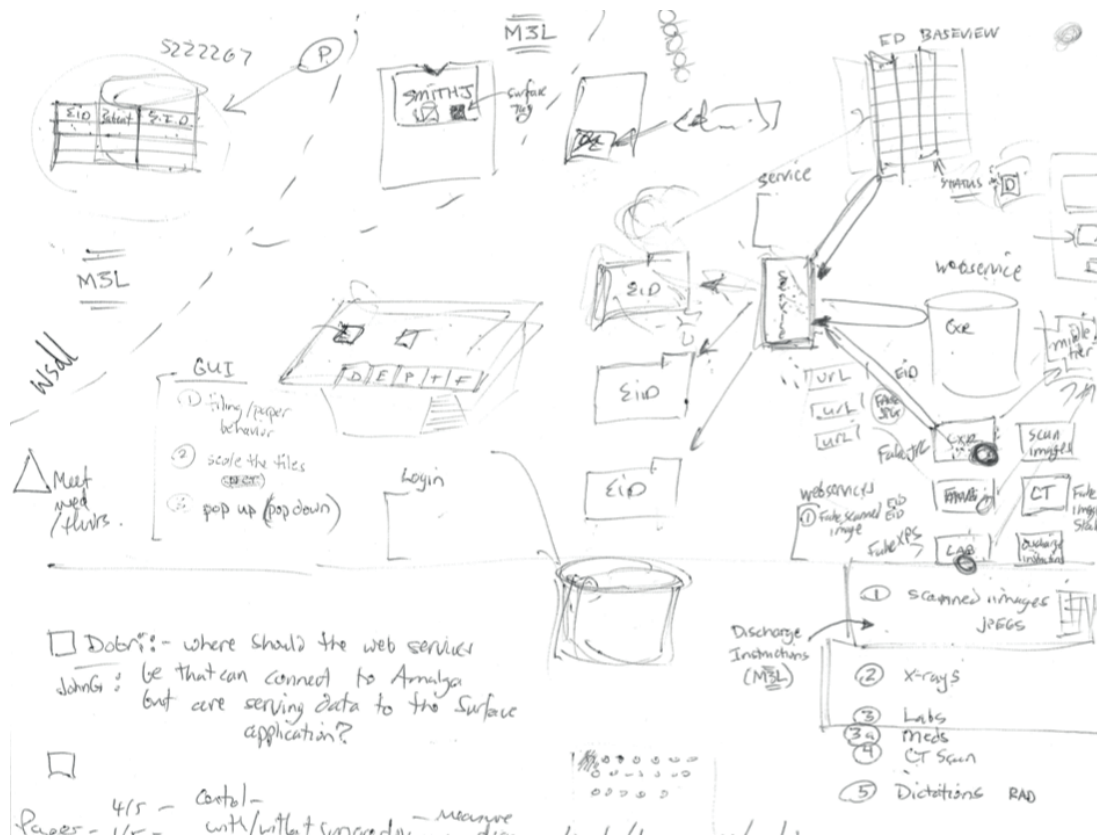
Videos (Angios / Ultrasound) (low/med)

Scanned docs (high)

Printed Docs (incl. discharge component) (high)

↳ VRS - parser - drop into EIO file.





Overheard in the ED – “Radios are useless: Use Cellphones” by a Physician

I did most of my observing in the Red Team area at the MedStar admissions area. From there I was able to observe serious emergencies and use of the triage bays. I spoke to a physician who told me that she encountered a serious issue on Monday (following the Red Line train collision) where a blood drawing had to be stopped mid-way through because a mismatch between the patient’s ID and their name was discovered (by the patient).

I observed how incoming emergency patients are logged in by a clerk at the door with a mobile terminal. Wristbands and stickers with barcodes are then printed (the wristband printer was out of order). These printed materials are then taken by a runner to the patients to have their wristbands attached and the covers with the identity information added to their charts. There was only one runner and she was giving some of these packets to other orderlies with instructions such as: “Give this to the patient in the Bridge with the burns”. This seems to be a serious potential flaw in patient identity fidelity.

Before attending this drill I had assumed that patients were given sequentially-numbered tags, wristbands, etc. as soon as they enter the door of the hospital and a photo taken and logged with their details. This does not seem to be the case and the working physicians had no interest in using the system, preferring paper notes. Other comments included: “The system is too complex and time-consuming. Just focus on giving us Physician ordering and discharge facilities as a priority. Make it as simple and quick as possible.” The possibility of using voice-to-text translation with mobile devices for physicians making initial diagnoses was postulated, with the ability to capture a face image and injury captures.

12.4 Questionnaire post-HealthTable

Questionnaire for Surface Patient Discharge Application

	<u>completely disagree</u>		neutral		completely agree
Did you enjoy the experience?	1	2	3	4	5
Did it help understand your diagnosis and the treatment you received?	1	2	3	4	5
Did it help you understand the how the medical data captured led to your diagnosis?	1	2	3	4	5
Did you feel your doctors / nurses communicated well?	1	2	3	4	5
Did you feel the doctors / nurses gave you care individually suited to your needs	1	2	3	4	5
Would you like to use the interactive table again on future visits?	1	2	3	4	5
Would you like to be able to upload materials viewed on the table to an online account for reviewing / sharing at home?	1	2	3	4	5
	<u>poor</u>		average		good
Please rate you level of understanding of your diagnosis and treatment	1	2	3	4	5
Please rate your overall satisfaction level with your visit to the emergency department	1	2	3	4	5

Additional Comments

Doctors

	<u>completely</u> <u>disagree</u>		neutral		completely agree
<input type="checkbox"/> Did you enjoy the experience?	1	2	3	4	5
Was the table application useful in helping explain the patient's diagnosis and treatment?	1	2	3	4	5
Was the table application helpful in easing the patient discharge disbursal?	1	2	3	4	5
Would you like to use this again in the future?	1	2	3	4	5

☐

Is there anything you would change / like to see added to the application?

Additional Comments

Date

Time Spent

Observations

Chief complaint

Consent Form

Patient Discharge Discussion with Electronic Materials on an Interactive Tabletop Computer

3rd August – 10th August 2009

Washington Hospital Center is taking part in a study aiming to develop new and exciting ways to interact with medical information and increase patient satisfaction. This will involve reviewing X-rays, CT scans, MRI scans, medical and chemical labs and doctors dictations on an interactive tabletop surface with a doctor or nurse, with the aim of increasing patient understanding and satisfaction with their visit to the emergency department.

I, _____, give the following consent:

- ☐ to allow myself to be a participant in the study for the purposes of research and development within the hospital and its technology partners.
- ☐ to allow video to be captured for scientific analysis and anonymously presented in academic conferences

Many Thanks,

Richard Morris, BSc B.P.S.

On behalf of Dr. Mark Smith

Washington Hospital Center

12.5 Tasks Considered in this PhD Project

Several tasks were considered for investigation in this project. They were devised through considering the physical and interactive potential of tabletop computers and existing research or commercial products.

12.5.1 Sports Training

Following interviews with squash coaches video supported analysis of performance is a key collaborative activity.

12.5.2 Ambient-Interactive Meeting Information Support

Display key topics being conversed in a tile format. Perhaps use voice recognition to make tile glow if a keyword is spoken. This then can be chosen to display contextual information. This would be a new type of device which crosses between ambient and interactive. Preparation would require a meeting facilitator (secretary) to create a list of twenty topics/people/business details to have as main areas which are likely to be usefully supported in discussion with extra information. Possibly, if voice recognition is advanced enough – a rolling list of verbalised topics on a side menu which can automatically link to contextual information.

12.5.3 Tourist Office

Use a tabletop to display information for families to explore a town and its attractions. Then to plan a day out, with the tablet making suggestions etc. Using

finger input to draw a route, or select and modify popular routes. Overlay food, history, colleges etc. points/areas of interest. To support tourists who want to build their own concept of the city, not to talk to agents, but who need access to good info and maps. Print out selected route and supplementary information.

12.5.4 Financial / Abstract Dataset Exploration

As a data mining exercise or to gain an understanding of a dataset, a tabletop tool allowing visualisation of data in an interactive fashion. That is to say, data points are selectable, groupable, zoomable, with a live-update summary shown to the side.

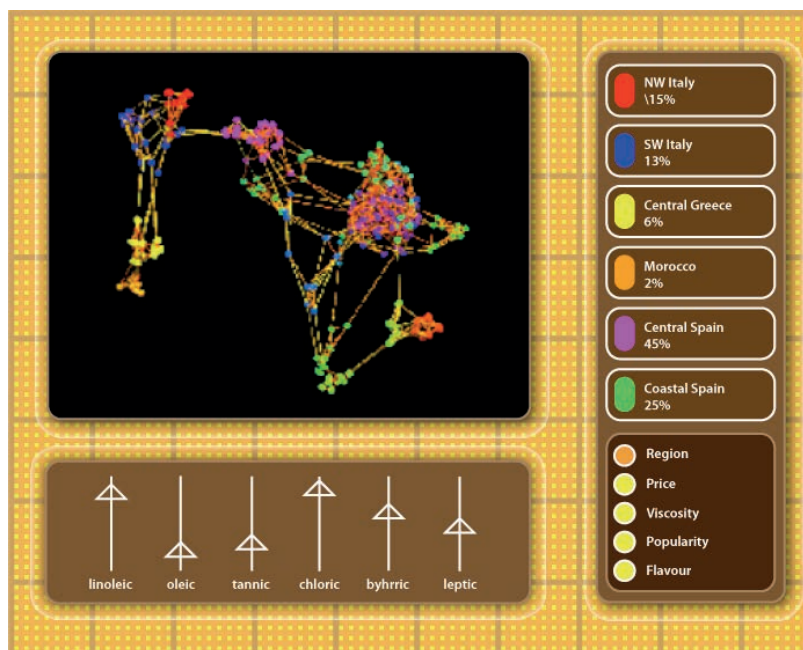


Figure 12.1: Analysis of olive oil constituents in 'mocked-up' tabletop application using the 'Haiku' data visualisation tool, following consultation with Prof. Russell Beale.

12.5.5 Disaster Planning

Environment Agency and council representatives working to simulate a disaster and plan emergency procedures. Ability to reflect, consider alternatives, allow equitable input from various stakeholders.

tabletop use in a planning task can be performed. The Environment Agency in the UK conduct disaster drills which involves collaborative planning for environmental disasters with collaboration from several agencies including the police and fire brigade. This task is also differs in social terms to the doctor-patient case study as there is less of a status differential between the users, i.e. a more 'symmetrical' user group.

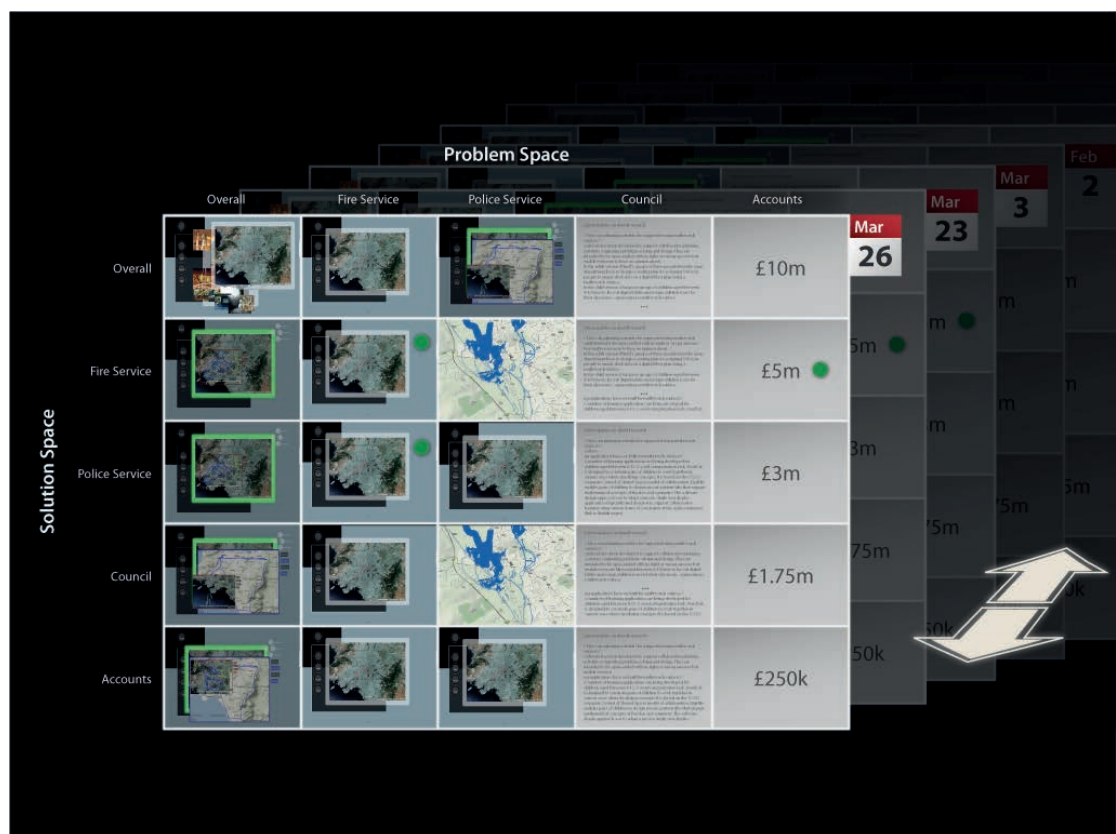


Figure 12.2: An imagination of a tabletop application for providing overview management of safety critical projects utilising a problem-oriented engineering approach.

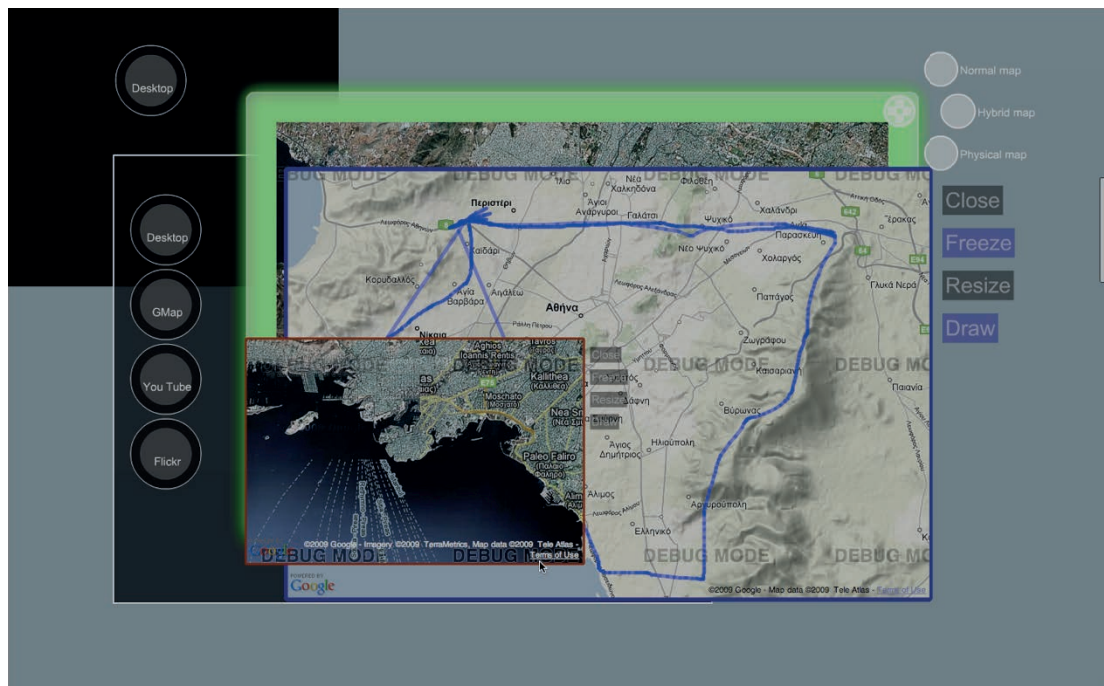


Figure 12.3: A working prototype of a map-based collaborative planning tool.

12.5.6 Architectural Consultation

Using tabletop to display things like energy use, heat/airflow to clients/stakeholders – to explore options regarding invisible aspects of design.

12.5.7 Cycle-lane Planning / Public Consultation

Using mapping to suggest and talk through possible options for a new cycle lane. Can overlay information such as traffic density, housing density, accident blackspots etc. to ensure an efficient and safe cycle lane.

12.5.8 Health Services Consultation

In situations where a patient is being admitted or discharged from a hospital there is a need for patients to give information or learn about diagnosed

conditions. An interactive tabletop allows doctors, nurses and patients to collaborate using digital medical media to enhance these interactions.



Figure 12.4: Patient education is a major issue in healthcare.

12.6 Glossary

- Approach
 - ‘Approach’ is used in this theory to describe a general way in which a problem was solved. This includes which factors are important to pay attention to, and the manner in which problem and solution spaces can be explored.
- Context
 - I shall use Dey and Abowd’s (2000) definition: “Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and the application themselves.” pp. 3

- Framework
 - In this theory, 'framework' is used to describe a theoretical structure which designers and researchers can apply to their own situation, inheriting the underlying conceptual organisation, in order to accelerate development of their own theories and systems.
- In the Wild
 - Referring to studies which take place outside of controlled laboratory settings. Also referred to as *in-situ* studies, the focus is on observing naturalistic interactions with technology, with intent to reach a more holistic understanding of the technology and its interplay with its environment. Users are typically not recruited specifically, and are not given scripts or training for the tasks they perform.
- Tabletop
 - In this thesis, tabletop refers to a digital interactive horizontal surface, resembling a regular tabletop, and the appropriate input, computing, and display technologies to allow representations on the tabletop to be manipulated. Microsoft Surface is an example.